Drawn by Mrs. E. Milne-Redhead

Frontispiece. *Coffea arabica* L. var. *arabica*

MODERN COFFEE PRODUCTION

By

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LONDON
LEONARD HILL [BOOKS] LIMITED
9 EDEN STREET, N.W.1

First published 1923
Reprinted *1956*, *1958*

PRINTED IN GREAT BRITAIN BY EBENEZER BAYLIS
AND SON, LTD., THE TRINITY PRESS, WORCESTER
AND LONDON

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PREFACE

My experience of coffee began at the age of twenty, more than forty years ago, when I took over the management of large coffee, rubber and cocoa plantations in Uganda, and made mistakes at that early age which were, perhaps, excusable, but which taught me to use common sense in later life, especially in regard to such necessities as erosion prevention. For seven years I was steeped in coffee and its cultivation and production from all angles, my conversation confined to coffee among planter friends until my world narrowed and I was in danger of becoming of no more consequence than a coffee tree itself.

Then, having some technical training behind me, I joined the Agricultural Department of Tanganyika Territory, and during service in that country spent five years in the Northern Province, mostly on the slopes of Kilimanjaro Mountain, and five years in the Bukoba District where the robusta coffee is grown. During those years I had much to do with the early organization of the Kilimanjaro Native Co-operative Union, and was responsible for the beginning of co-operative marketing and grading. At Bukoba, also, I initiated the arrangements for grading at the Lake Port, but was frustrated in an attempt to introduce a higher quality first grade than was subsequently adopted.

Naturally I had to visit the coffee areas of Kenya and read a great deal about coffee production in other parts of the world, and if this book has a strong East African flavour it is not alone because my practical experience was obtained there, but because of an appreciation of the fact that the methods of cultivating coffee in East Africa are now of the highest order, and are seldom equalled elsewhere.

For many years I have wanted to write a book on coffee, and at last was given my chance by Messrs. Leonard Hill Ltd., without whose help, and in particular that of Mr. R. G. Thixton, it would have been hard to complete the task. It has, indeed, been an undertaking, consuming more time than was anticipated on account of the research required and the mass of literature that exists in so many languages. Then there was the confusion which confronted me in the botanical field, relieved at last by the realization that so many mutants, forms, and so-called species had arisen in cultivated fields and could hence be relegated to cultivated varieties named under the new international code for cultivated plants.

With the new arrangement many may not agree, but I have been in close consultation with my friends at the Royal Botanic Gardens, Kew, who have given me considerable assistance. Doubtless the taxonomic confusion will be further disentangled by them in course of time. Meanwhile, my grateful thanks are due to the Director of the Royal Botanic Gardens, Kew, for the help I have received, to the Keeper of the Herbarium, and especially to Mr. A. A. Bullock who has been kind enough to read and correct the proofs of the chapter on botany.

In accordance with international procedure, specific names are not now begun with capital letters, and all are printed in lower-case italics, while 'cultivars' are printed in Roman characters. As for botanical varieties the

specific name must be repeated in italics for the variety including the type of the specific epithet, hence the variety including the type specimen of *Coffea arabica* must be named var. *arabica*, and cannot be called *typica* as it has been in Brazil until recently.

In the field of genetics, full credit must be given to the wonderful achievements of Drs. Krug and Carvalho at the Institute of Agronomy in Brazil, where, as a result of their work and that of their colleagues, the breeding and improvement of coffee has begun on the sound basic knowledge which they have given to the world. I was fortunate to meet Senhor A. Carvalho at the Thirteenth International Horticultural Congress in London, held in 1953, and he generously gave me full permission to quote from the written reports of their researches.

When the historical movements of planting material about the world are studied, it is interesting to find that there were two distinct and common forms of Arabian coffee originating from the neighbourhood of Aden; one with horizontal laterals and bronze-tipped foliage which became known as the type, the other with a more upright growth of the laterals, and green-tipped foliage, which the French called Bourbon coffee and which has since become known as var. *bourbon*. A botanical study of Arabian coffee would appear to confirm these two as botanical varieties, i.e., var. *arabica* and var. *bourbon*, and genetical studies in Brazil go still further in proving that one is dominant and the other recessive, so that these two have given rise to all the mutants, and hybrids formerly known as varieties, but which must now be listed as cultigens.

Though there is as yet no proof that all the self-sterile species follow the same trend, mutants of a similar kind have been found among *Coffea canephora*, and there are two very distinct forms, one with upright and the other with a spreading growth. It is interesting to speculate and consider whether divergent forms are present in Liberian coffee and in the *C. excelsa* group as well, giving rise to all the other merging forms and accounting for some of the confusion.

Emphasis has been given to the fact that coffee is an evergreen which needs moisture all the year round. Agreement is expressed with many authorities who point to the fact that sufficient moisture is all-important, especially sub-soil moisture during the drier months of the year. Drier weather may be necessary for short spells but there must never be a deficit of moisture in the sub-soil. Wherever the rainfall is short, moisture conservation is of the greatest importance, for it is moisture then that controls the yield while manuring brings little response. In short-rainfall areas cover crops, temporary shade plants, and weeds create moisture deficits which are dangerous, and lead to leaf fall and die-back. A most important revelation is the fact that intense light closes the leaf stomata and brings assimilation to an end for most of the day, pointing to the need for a light overhead shade in all regions where cloud and mist are insufficient to reduce the daylight by the requisite amount.

In the chapters on starting a plantation and on maintenance, information is given on the use of explosives and on anti-erosion methods because experience has shown how useful such information would have been when I began to cultivate coffee myself.

The literature on coffee is prolific and goes back many years. To search for and read all that has been written would be a tremendous task, and this

book has taken several years to write and more hours have seemingly been wasted than I care to remember. It has been impossible to mention every authority. Much of the literature is obsolete in the light of modern knowledge; some is definitely misleading; and a great deal is based on such confusion concerning taxonomic determinations that much good work in the past has been rendered unsound. For reasons such as these, references may have been deliberately omitted. Moreover, being human, I am likely to err somewhat seriously on account of ignorance. I therefore seek forgiveness in regard to important omissions and admit to having floundered, engulfed in such a sea of literature that it made me fear my work would never be completed.

Wherever possible, references have been chosen which themselves contain long bibliographies, as these will guide students into other fields and to many more writings on the subject. In this manner many seeming omissions have been avoided.

In addition to those already mentioned I must record my grateful thanks to the Director of the Colonial Plant and Animal Products Department, London, and those in the library there who have assisted me so willingly, and to the Director of the Commonwealth Bureau of Horticulture and Plantation Crops who listed 235 references for me and pointed to a bibliography of 1,840 more. I must also thank the Foreign Agricultural Service of the United States Department of Agriculture for presenting me with two volumes of abstracts from the literature on coffee, and for their help in many other ways; also the Directors of Agriculture of Kenya, Uganda, Tanganyika, the Federated States of Malaya, and their research officers for information, photographs and encouragement.

Special acknowledgement must be made of considerable assistance from Mr. A. E. Melville, B.Sc., A.I.C.T.A., Senior Entomologist (Coffee) and Mr. R. W. Rayner, B.A., A.I.C.T.A., Plant Pathologist and Physiologist, Coffee Services, Kenya Colony; also from Mr. L. M. Fernie, Horticulturalist, Lyamungu Research Station, Tanganyika Territory, for notes, memoranda and illustrations. Licenciado Dn. Juan Rebolledo Clement of the Comisión Nacional del Café, and Mr. James McCrae of Mexico, have been most kind in supplying literature and illustrations, and so has Ir. G. G. Bolhuis, of the Landbouwhogeschool, Wageningen, Holland.

Messrs. John Gordon & Co., Wm. McKinnon & Co. Ltd., Davidson & Co. Ltd., and E. H. Bentall & Co. Ltd., have all most willingly offered or given help. I am deeply indebted to Mr. John D. Gordon for having read the chapter on the preparation and curing of coffee and for his meticulous comments on the original draft; also to Messrs. Wm. McKinnon & Co. for their trouble in obtaining some illustrations from overseas.

My grateful thanks are due also to Mr. W. Victor Harris, M.Sc., F.R.E.S., formerly Entomologist, Tanganyika Territory and now attached to the Commonwealth Entomological Institute, for correcting the draft of the chapter on pests and for his four excellent drawings. Then there are Mr. Pierre G. Sylvain, Coffee Specialist, Food and Agriculture Organization, who gave me advance information following his visits to Ethiopia and the Yemen Territory; the Commercial Attachés of the French, Belgian and Portuguese Embassies, and many others with whom I have corresponded and who have given me assistance without stint.

Lastly I am indebted to the late Sir Harold Tempany, C.M.G., C.B.E., for

his encouraging interest, and all those who have permitted me to draw so liberally on their writings or reproduce illustrations that have been published elsewhere.

The aim in this book has been to supply the planter, the student, and the field extension officer with a treatise in simple language which may be informative, and of interest. Coffee is an orchard crop and should therefore be classified as horticultural, yet it is wise to link it with agriculture for fear, as too often happens, that it becomes a monoculture. It does not matter whether coffee is planted as an adjunct to mixed farming or as an integral part; the two should go together for preference, provided coffee is not treated as an agricultural crop. A considerable acreage of coffee is more likely to succeed as part of a mixed farm, where residues for mulching and food for labour can be grown.

I believe that a man who has spent a considerable part of his life growing coffee, and on extension work in coffee country, has a right to air opinions and advance ideas that may prove of value, albeit I have endeavoured to say nothing that has not proved sound in practice or has been based on the results of reliable research.

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Chapter I

THE EARLY HISTORY OF COFFEE

PRIMITIVE USES, AND THE ORIGIN OF THE COFFEE TRADE

SINCE Africa is the home of so many of the economic species of coffee, one must delve into African history to discover the probable origin of their use. Both Speke and Grant found robusta coffee planted near the homes of the Baganda people when they first visited Uganda in 1862. The Africans had taken coffee into their ritual of blood-brotherhood, and the chewing of dried berries of robusta coffee had also become widespread, particularly during arduous campaigns or long journeys.

The fact that coffee berries normally had two seeds of similar shape and size within each fruit suggested to the African mind the idea of two brothers born of the same stem. When two Baganda desired to become attached to each other within the meaning of blood-brotherhood, they separated the two beans from a berry, each smeared one with his blood, and having exchanged the beans, these were solemnly chewed to consummate the union of eternal friendship.[13]

Primitive man must have suffered famine and hardship in each generation. Droughts, floods, locusts and the depredations of marauding beasts such as wild elephants, no doubt destroyed his crops. The raiding of other tribes and prolonged wars between different races caused villagers to flee their homes and trek hungry and exhausted to find new regions in which to settle with greater safety. There must have been many times when the remnant of a tribe survived by feeding on the products of wild plants. Doubtless the birds and animals were watched to discover what they fed upon, and everything must have been tried and chewed to see if it was edible.

The ripe fruits of some of the coffee species are sweet to the taste, and they are attractive to birds and animals. The author himself, when biting and examining parchment coffee to test it for dryness, has unconsciously chewed the beans in his mouth for a while on a hot day, and one can understand how such a habit could grow, without volition, spurred on by the hidden stimulant within the bean, until chewing them would become a comfort to a tired man on a long march.

In some such manner the chewing of coffee must have become a practice, and the wild fruit used, until it occurred to the inhabitants that it would save trouble to grow bushes of their own. According to A. S. Thomas,[13] large quantities are still collected under licence from the Uganda Forestry Department, especially in the Kisai Forest of Toro, since the consumption by the Africans for chewing is still considerable and widespread. The fruit is gathered just before it is ripe, and then steamed and dried. Today the Uganda African drinks tea, despite the fact that he has to pay for it, and coffee is freely obtained throughout his country.

The planting of seedlings did not take place for a long while, since it was usual to take large cuttings about 3 feet long, and 1 inch thick, and plant these bent in the shape of a bow, so that both ends were inserted in the

ground to root and form a living arch from which several suckers sprouted. Visitors were often given dried berries to chew, and until recent years, no Muganda African planted his own coffee. It was always the custom for a visitor to do this as a mark of friendship and esteem.[13]

The more coffee was grown, the more likely it was for escapes from cultivation to take root in the neighbouring forests where robusta had not grown before, and it is difficult to say with any degree of certainty today, whether robusta coffee is truly indigenous in all the Uganda forests.

Robusta and Liberian coffees in their varying forms are found throughout a vast area of Western Africa, where explorers did not record their use by any of the indigenous people before the early Portuguese adventurers took these species into cultivation at coastal settlements. Liberian coffee is mentioned by Afzelius as being cultivated in Sierra Leone in 1792.[4]

'Shari' coffee from *Coffea excelsa* was not discovered until 1904[2] but the 'highland coffee' of Sierra Leone, now known as *Coffea stenophylla* G. Don., was taken into cultivation by the Portuguese in Lower French Guinea and Sierra Leone in very early days.

None of these coffees became of such world-wide importance as did Arabian coffee, which most authorities agree originated in Abyssinia. There are accounts of Arabian coffee having been chewed by the aborigines of Abyssinia to comfort and stimulate them on arduous journeys.[4] In his *Travels to Discover the Source of the Nile* in 1678, Bruce states that when the people of Ethiopia journeyed over deserts into Abyssinia, the only food they carried was ground roasted coffee mixed with oils or fats, made up into balls the size of a billiard ball. These were carried in leather pouches, and one ball was said to give sufficient sustenance for twenty-four hours. It is not certain, however, whether the coffee used was of the robusta, or Arabian, kind. It is very probable that Arab slave raiders noted these practices, or that captured slaves were found with dried coffee fruits in their possession. In some such way the principal coffee of commerce might well have been taken to Arabia, and have been grown in gardens at high altitudes, whence it may later have escaped and grown wild, albeit there are no authentic records of *Coffea arabica* L. having been found growing wild in the country that has given it its name.

There is no reputable record of coffee having existed in Arabia during the thirteenth century, and it is not mentioned in the Koran or Hebrew Scriptures.[2] Chevalier[3] reiterates the general belief that Arabian coffee was first cultivated in Arabia during the fourteenth century, and nowhere else until early in the seventeenth century. Though the exact progress of events is unknown, it is certain that the use of coffee and of Arabian coffee in particular, developed in Arabia during the intervening fifteenth and sixteenth centuries, from the mere chewing of the dried seeds and fruits to the brewing of beverages from the ripe fruit and possibly from the roasted coffee beans as well.

There are legends, of course, in which little reliance can be placed, such as the incident which is said to have been recorded in 1675 concerning the camels and goats belonging to a monastery. The prior is supposed to have noticed that the animals were restless and much excited after they had eaten the leaves of a certain plant, to wit coffee. He caused a brew to be made from the leaves, and after testing this himself he is said to have given it to his monks to drink to prevent them sleeping during their nightly devotions.

It seems clear that in the beginning a concoction was made from the thin sweet pulp of the fruits of *Coffea arabica*, L. which the Arabs called 'Kahwah', a name they used for wine, and the theory is held that the original beverage made in Arabia from coffee was an intoxicating liquor, as it may well have become at times if it was allowed to ferment.[2] In arabic and kiswahili, coffee is still called kahwah, kawa or gawah—terms which are generally understood to mean something which tastes bitter. It is said that the art of roasting and preparing a drink from the ground beans was discovered soon after the knowledge of the use of coffee had spread into countries bordering Arabia, and possibly first of all in Persia.

How the Habit of Coffee Drinking Spread

Although the exact date of the introduction of *Coffea arabica*, L. into Arabia is unknown, a treatise written by an Arabian sheikh in the year 1566, gives credit to a Mollah named Djmaleddin Abou Elfrager who is said to have introduced coffee into Arabia from Abyssinia in the fifteenth century, where its use as a beverage was soon preferred to an infusion formerly made from the leaves of *Celastrus edulis* Vahl. Coffee was said to help people remain awake when they wished to work or travel during the night, and as the taste for it became acquired, people drank it because it appealed to their taste. The beverage became popular in spite of the fact that a group of strict Mohammedan priests declared it to be an intoxicant, and therefore prohibited by the Koran.

The practice of coffee drinking soon spread to Mecca, Medina and Syria, and via Syria and Aden to Cairo and throughout the Moslem Middle East about 1510. In 1511, coffee drinking in Mecca was forbidden on religious grounds by Khaine Beg, who was then the Governor. His successor, however, waived the order, and permitted drinking to begin again. Twelve years later the Priest Abdallah Ibrahim denounced coffee drinking in the Mosque of Haffanaine, and trouble ensued again between those who condemned coffee drinkers as irreligious, and others who considered it a harmless pleasure. Friction reached such a pitch that Sheikh Obelek is said to have called a meeting of the influential men of both factions, and having listened to their complaints he caused each to be served with a bowl of most delicious coffee. The Governor drank his, and then withdrew, after which the opposition to coffee drinking abated.[2]

While the practice of coffee drinking grew prevalent throughout the Middle East, and reached Turkey about 1554, the suspicions with which it was met by the Mohammedan peoples were doubtless on account of rumours which had preceded the actual arrival of coffee in each new place. Word of its use, and of its comforting stimulus, would doubtless have been carried in advance, and have been exaggerated by those travelling on camel-back across the desert, and one must remember that a beverage made from the ripe fruit might well have been alcoholic in the beginning. Because of slow travel, the illiteracy of the Mohammedan people, and the vast distances covered, it would not be easy for a new beverage made from the roasted coffee beans to become popular, and to prove itself as non-alcoholic.

Chenney recounts how men from Damascus and Aleppo opened coffee houses in Constantinople, now known as Istanbul, and of how the attraction of these coffee houses began to affect the attendance at mosques. The

religious leaders objected, and persuaded the Sultan to issue a decree forbidding the practice of coffee drinking. Doubtless they used every reason they could think of to prove the practice irreligious, harking back to those ancient rumours to confuse the issue. Sultan Amuret the Third closed the coffee houses, but his successor had them reopened, and since then coffee has become indispensable throughout the Turkish Empire.

Chenney puts on record how a German physician, by name Rauwolf, was the first to bring news of the use of coffee to Europe, following his travels in Syria in 1573, though coffee was not used in Europe until soon after 1600, when a Venetian named Pietro della Valle obtained a supply from Turkey. It was later brewed and on sale in Rome during 1625. Roasted beans and brewing apparatus were introduced to France from Turkey by De la Haye in 1644, and almost at the same time Pietro della Valle carried coffee to Marseilles, whence it was taken as a curiosity to Paris. By 1660 several consignments of coffee beans had been shipped from Alexandria to Marseilles, and less than ten years later coffee drinking had become popular among the aristocracy. The first coffee house in France was opened in Marseilles in 1671, and during the following year, a man named Pascal owned a coffee house in Paris.

The seafaring folk of England also brought stories to London about the use of coffee, soon after the beginning of the seventeenth century, but there is no authentic account of its introduction for actual use until 1650, when a Jew from Lebanon by name Jacob, Jacobs or Jobson, is said to have opened the earliest coffee house at the 'Angel' in the parish of St. Peter in the East, Oxford.[14] Another celebrated house was 'Mol's' coffee house at Exeter. In 1652, an English merchant of London who traded with Turkey, by name Daniel Edwards, brought coffee beans to England. Following a tour in the East he brought home a Ragusan youth from Smyrna named Pasca Rosee (some authorities spell his name as Rosco, or Pasqua Rossie) whose duty it was to prepare coffee for Mr. Edwards. His London friends took such a fancy to the new drink that despairing of keeping them out of his house, he is said to have established Pasca in the first London coffee house in St. Michael's Alley, Cornhill,[11] where a plaque presented by the London Buyers' Association in commemoration of the event was unveiled on 25th March 1952 by Sir Leslie Boyce, then Lord Mayor of London. Within a few years a number of coffee houses had been opened, customs excise duties were imposed, and in 1663, coffee houses had become licensed premises which advertised coffee as a tonic brew.

In 1675, by which time there were nearly three thousand coffee houses in England, King Charles II denounced them as seditious meeting places. He issued a proclamation rescinding their licences, but had to withdraw this edict within a few days on account of the tremendous opposition that he had aroused. Attempts which were then made to check the import of coffee beans resulted in smuggling, and all ideas of hindering the trade had to be abandoned. Thus coffee was in general use in Britain by 1688, and the coffee houses became centres where news was exchanged and where affairs of the day were discussed by intelligent men without any opprobrium attaching to their presence.

As the years sped by, the fame of coffee as a refreshing and satisfying beverage spread throughout Europe to Holland in 1664, and thence to Germany and Austria—to Vienna—from Turkey in 1683, after which a trade began.

Coffee houses were opened at Hamburg in 1687, at Leipzig in 1684, at Danzig and Wittenburg in 1700, and in Berlin in 1721. Sweden and Denmark took the habit from Germany in 1756, and coffee drinking began in Russia about 1700.

The practice of coffee drinking spread to the Western Hemisphere via Virginia from Britain in the pre-revolutionary days, but as the coffee houses degenerated into taverns where alcohol was also on sale, these places were neglected by gentlefolk. Even so, the habit of drinking coffee grew until, in the United States today, it is as important to the happiness and comfort of the people as it is to the Turks. It would be a major disaster if through any cause coffee were no longer procurable.

The Early Movement of Seed and Planting Material about the World

The channels through which coffee was traded from Arabia and the Middle East to Europe were not easy in those early days and the product was costly to import. It was only natural for those countries that had acquired colonies to consider the possibility of establishing coffee plantations overseas. The Yemen country of Arabia had already begun to cultivate coffee in the mountainous hinterland on quite a large scale, to supply the ever-growing trade across the desert by caravan, and through Aden and other coastal settlements to Egypt, Syria and Turkey. Several expeditions were sent by the Dutch, the French and the British to obtain seed or planting material from Arabia.

It would appear that the Dutch were the first to initiate action in 1690, when Nicholas Wilser, Governor of the Dutch East Indies, instructed Van Horn, the Governor of Batavia, to obtain seeds from Arabia.[2] According to Ukers,[14] a coffee plant had been taken to Holland from Mocha in 1616. He further states that the Dutch started planting coffee in Ceylon in 1658, and that the Burgomaster of Amsterdam caused plants to be shipped from the Malabar Coast to Java in 1696; these had been grown from seeds of *Coffea arabica* originally taken to Malabar from Arabia.

These plants were grown on the Kedawoeng estate near Batavia, but they were all subsequently lost by earthquake and flood in 1699.[9] In that same year, a certain Zwaardkroon was sent to Malabar to obtain more planting material, which was successfully established and became the origin of all the early coffee in the Dutch East Indies. In 1711 the first consignment of 894 lb. was shipped to Amsterdam,[9, 14] where it was sold by auction in 1711 or 1712.[6] In 1706, a coffee plant was dispatched to the Amsterdam Botanical Gardens, where it afterwards produced seeds and seedlings which were distributed to the principal botanical gardens in Europe.[14]

In 1714, a young and vigorous plant about five feet tall is said to have been sent by the Burgomaster of Amsterdam to Louis XIV of France at the Chateau of Marly, but the following day it was transferred to the Jardin des Plantes in Paris, where it was received with appropriate ceremonies by Antoine de Jussieu. This produced more seeds and plants in due course.[9, 14] In 1719, Arabian coffee was imported into Surinam, Dutch Guiana, from Amsterdam.[9] The cultivation of coffee was later extended to Sumatra, to the Celebes, Bali, Timor and several other islands of the Dutch East Indies, now called Indonesia. Most if not all of the coffee which was grown in the

beginning by the Dutch, appears to have been a chance selection of the *Coffea arabica* L. var. *arabica*, known in Brazil as var. *typica*.

In 1708, two French vessels called at the port of Mocha, where seeds and sixty small plants were purchased from an Arabian sheikh.[3] These were taken to the island of Réunion but failed to grow, and only two plants survived from a second introduction of seed in 1715. The French persisted in their efforts, however, and were more successful when, in 1718, they tried a third time to grow coffee from seeds and planting material taken from Mocha to Bourbon in the island of Réunion. At last a small plantation was established which fruited abundantly in 1721, and the variety which did best of all became known as Bourbon Coffee. Hence it was from this source that the 'Bourbon Coffee' of the world was propagated.

It is not surprising that difficulties were encountered in establishing coffee in cultivation so far south of the equator. At the latitude of 20° south, cold weather and ground frosts might be expected in the hills, and cold kabatic air currents may flow into low-lying valleys during the winter months. Much would depend on the choice of a warm and sheltered locality.

The Dutch introduced Arabian coffee to Ceylon somewhere between 1690 and 1720 while they were in possession of the island. Legendary references to an earlier introduction seem based on the fact that it had been common practice to decorate the shrines and temples with the jasmine-like flowers of other species of coffee of no economic interest, which were indigenous in that country. British interest in coffee planting in Ceylon started after Kandy was captured in 1815. The coffee abandoned by the Dutch was found growing here and there and planting began soon after 1820. Sir Edward Barnes established a plantation in 1825 and the West Indian methods of planting were introduced. A flourishing industry began despite our lack of knowledge, in those days, of how to treat the crop. The growth of the industry was rapid.

Speculation and financial stringency resulted in a crisis in 1847, when many estates changed hands. Much of the older coffee planted by the Dutch had either died or grown wild, and several of the British estates failed on account of lack of knowledge regarding the choice of site, or of how to cultivate the crop. These were abandoned about this time and left to become overgrown. Naturally this encouraged pests, a number of which began to be a nuisance, among which green scale, caterpillars, monkeys, rats and squirrels have been mentioned.[11] Then, when knowledge of tropical planting was still in its infancy, the leaf rust disease *Hemileia vastatrix* made its appearance in 1869. It spread rapidly and yields dropped from an average of 7 cwt. to only 4½ cwt. per acre, giving an impression at the time of failing fertility. It was not until the end of the year that the disease was reported.

There is no doubt that the rust disease started in Ceylon, possibly because the disease was there already on the indigenous species and it found Arabian coffee a better host. Since crop yields dropped below the limit of commercial profit, the planters turned their interests to Chincona, rubber and tea instead.

The leaf rust disease appeared in Java in 1878, and later it spread to Fiji, the Low Veld of South Africa, and the Philippines. Parts of East Africa were free from the disease until the nineteen-thirties, especially the Southern

Province of Tanganyika, and leaf rust had not apparently broken out in Nyasaland by the time the coffee industry languished.

The *Hemileia* disease menaced the plantations in India and the Dutch East Indies, but the Dutch turned to the cultivation of the more resistant robusta coffee instead, and started a considerable programme of hybridization between the Arabian, robusta, Liberian and excelsa coffees. In India a great deal of selection work was done in later years, and the hardy 'Kent's' variety of Arabian coffee was discovered in Mysore.

According to Indian tradition, coffee was introduced into India by a Moslem pilgrim by name Baba Budan, as early as 1600 or 1695; he, it is said, planted his seeds near his hut at Chikmagalur in the mountains of Mysore.[14] The British are said to have introduced coffee to the Malabar coast in 1700, obtaining their planting material direct from Aden, but this does not agree with reputable records to the effect that the Dutch took plants from the Malabar coast four years earlier in 1696. It seems that plantations were laid down by a Mr. Cannon in 1830, and by a Mr. Glasson in 1840. The industry flourished, and by 1900 Arabian coffee was being cultivated in the State of Mysore and Coorg on the southern slopes of the Western Ghats and the Nilgiri Hills, also in Travancore, and in the Shevaroy and Palni Hills of Madras.

After the leaf rust had attacked the coffee at lower altitudes in Java, the robusta coffee was planted in 1900[9] and from that time onwards a great deal of work was done in an endeavour to hybridize coffee and gain good quality together with immunity to the disease. Robusta coffee planting was also begun in India for fear that the disease would prove disastrous.

History is somewhat confused regarding the movement of planting material to the Western Hemisphere. Whereas every writer recording historical events tries to put his finger on the first date and the first event, with coffee there were undoubtedly several movements at about the same time, and many of the following movements have not been recorded, or they may have become confused with the first.

There is little doubt that the Dutch took coffee into Surinam in 1719. The coffee plant given to Louis XIV in 1714 by the Dutch Burgomaster of Amsterdam produced seeds and young plants, but only one use of these plants is mentioned. Some were dispatched, it is said by the King's orders, and in the care of a Lt. Desclieux (often spelled Des Clieu) to the island of Martinique in 1717[2] or 1723[6]. According to the most trustworthy data Desclieux embarked at Nantes in 1723, and on arrival, planted the only plant which survived the voyage on his estate in Précheur, where it grew successfully.

Stories tell how Lt. Desclieux tended the last surviving plant most carefully on the protracted voyage through tempests and tropical heat, when fresh water ran low, and he sacrificed part of his own meagre ration to keep the plant alive. Undoubtedly the plant was the progenitor of cultivated coffee on the island of Martinique, if not the ancestor of South American plantations. It is worthy of note that the Brazilians celebrated the bicentenary of the start of their coffee industry in 1926,[6] which would make the date of the first introduction of coffee during the year 1726.

The French Governor of Cayenne is stated to have obtained planting material from Surinam in 1722, and Chenney[2] quotes from his information that many seedlings were later taken from Cayenne to the mainland. It is

probable, however, that the French in Cayenne and in French Guiana obtained seed from Martinique a few years later. It seems, therefore, that there is some doubt as to whether the Dutch importation into Surinam, or that for which Lt. Desclieux was responsible, was the origin of the coffee ultimately taken to Brazil. Both came from the same Dutch stock and were probably the variety now known in Brazil as var. *typica.* The French later took the var. *bourbon* coffee from Réunion to their West Indian colonies.

About this time coffee planting was proceeding in both Dutch and French Guiana, and it is said that the separate authorities were so jealous of their success that they made the export of ripe berries or planting material a serious offence. A story is extant about a dispute which began concerning the boundary of these territories, when a Brazilian official from Para by name Palheta was called in to adjudicate. It is said that the Brazilian made love to the wife of the French Governor, and persuaded her to give him a handful of ripe coffee berries in the presence of her unsuspecting husband. These she concealed in a bouquet of flowers which she presented to Palheta at a banquet given on the eve of his return to Brazil. He sailed away to the mouth of the Amazon, where coffee plants were successfully raised.

There may not be much truth in this story, but other authorities state that Palheta or Palheto introduced seed to the valley of the Amazon about 1723 from Cayenne or French Guiana.[12] Coffee plants were raised at Para and afterwards at Maranhão, but planting material was not taken south to Rio de Janeiro until much later. The first coffee estate is said to have been planted in the Province of Maranhão in 1767, and in the Rio de Janeiro neighbourhood in 1774. A Belgian monk by name Molka is reported to have carried a plant from a Maranhão estate, and this he planted in the garden of the Capuchin monastery of Adjuda. Seedlings from this tree were used to plant up an estate, whence seed was eventually distributed throughout Brazil by both Joachim Bruneo, the Bishop of Rio de Janeiro, and the monk Molka.

Elsewhere it is recorded that a judge of the Court of Appeal by name João Alberto Castello Branco, ordered seed from the north of Brazil, and this was eventually planted in the garden of the Italian Capuchins hospital, Barbonos Street, Rio de Janeiro, and in the Park of João Hopfman (now S. Christovão Street).

It is thought that the garden of the hospital provided seed for the original plantations in the States of Rio de Janeiro, Minas Geraes, and São Paulo.[12] Members of the Church took a great interest in its propagation, for the Abbot Lopes da Fonseca had a large plantation on his Mendenha estates at Campo Grand near Rio de Janeiro, and Dom José Salustiano, Bishop of Rio, ordered seed which was gathered in the gardens of the Capuchins to be given to the Abbot Coito, who lived near Pezende in the Province of Rio de Janeiro, also to the Abbot João Lopes of the District of São Gonçalo, in the same Province.

Thanks to this interest displayed by the Church the cultivation of coffee spread, and coffee had become well known as a beverage at São Paulo on account of the efforts of Fr. Manoel José. By 1835 coffee growing had made great strides, especially in the Province of Rio de Janeiro. Encouraged by this example, planting started in the north of São Paulo, and then Campinas became an important centre of production. A number of agriculturalists from various parts of Brazil, and especially from Minas Geraes, were attracted to these successful regions by the rumours of wealth.

Coffea arabica L. Rough copy of a sketch by Antoine de Jussieu, 1713

PLATE I

From Campinas on the one side, and from Guaratinguetá, Pindamonhangaba, Taubaté, São José dos Campos and Jacarehy on the other, planting spread rapidly towards the interior, until of the 171 municipalities of São Paulo, 150 became large-scale producers.[12] Coffee was taken to Bahia towards the end of the eighteenth century, from Bahia to Pernambuco, whence it spread to Parahyba do Norte.

All this coffee appears to have been of the same strain, and it became known as the 'Nacional' coffee of Brazil. Later the French appear to have brought the var. *bourbon* to the West Indies, and thence to many of the Central American States and parts of South America. There were thus migrations of the two sorts, which, in course of time, overlapped. Venezuela, Colombia, Ecuador and Bolivia obtained their supplies from the West Indies and began planting about 1784, and so many movements took place that few of them have been recorded. The Venezuelan industry is said to have been started near Caracas by the priest José Antonio Mohedano with seed imported from Martinique, and Bolivia took seed from over the border in Venezuela.

The British procured seed for Jamaica also from Martinique about 1730, and its cultivation in the island was vigorously encouraged by Sir Nicolas Lawes in 1732. Coffee is supposed to have reached Santo Domingo from neighbouring islands by the aid of birds about 1735, and a few years later coffee planting had started and soon became the chief source of wealth. Then came the revolution which severed the ties with France. The coloured liberator Toussaint Louverture may have tried to save the coffee plantations from harm, but the inflamed slaves murdered their masters and also destroyed the crops, so that the coffee industry virtually came to an end in Haiti and Santo Domingo in 1791.[6]

In 1748 Don José Antonio Gelabert is said to have taken coffee seed to Cuba from Santo Domingo. Porto Rico received seed, probably from the French islands of the Lesser Antilles in 1750, and began planting about 1755.

The Spanish voyager Don Francisco Xavier Navarro is credited with having introduced coffee into Costa Rica from Cuba in 1779.[14] El Salvador is also supposed to have obtained planting material from Cuba about 1840. A Don Juan Antonio Gomez is said to have instituted intensive cultivation in the State of Vera Cruz in 1817. Mexico began planting about 1790, using seed from the West Indies, and Guatemala received material for planting somewhere between 1750 and 1760. Cultivation began in the Hawaiian Islands in 1825 when seed was obtained from Rio de Janeiro.

Meanwhile Spanish missionaries are said to have introduced coffee to the Philippines from Java in 1740. The French are said to have introduced coffee plants to Tonkin and Indo-China in 1887, and coffee growing began in Queensland in 1896.

Turning to the African continent, and to the Central and East African territories in particular, the Roman Catholic mission stations were chiefly responsible for establishing plants of Arabian coffee in their gardens to supply themselves with coffee beans. Though Abyssinia was not far away as the crow flies from the Kenya highlands, coffee seed of the bourbon variety was brought from Réunion to mission stations in Kenya. Seed was obtained from these to start some of the first coffee plantations, not many years before the first world war.

Nyasaland had already started an industry. Coffee was introduced into Nyasaland in 1878, and by 1891 there was a flourishing industry in the Malanje District.[1] It is said that the seed introduced originated from the Blue Mountain region of Jamaica,[7] but the strain became known in East Africa as the 'Nyasa' variety, which proved to be similar to the 'Nacional' coffee of Brazil, and is now listed as *Coffea arabica* L. var. *arabica*. Though coffee became an important crop in the Shire Highlands, the industry ultimately languished and died out, largely because of inexperienced handling at the start. Other causes were the marginal climatic conditions and the incidence of root diseases and pests such as the white stem borer and sucking bugs.[5] On account of overbearing in early growth, followed by poor yields, coffee was abandoned in favour of tobacco and tea, and no exports have been recorded since 1947.

The 'Nyasa' or var. *arabica* strain was taken to Uganda from Nyasaland about 1910, and was largely used for coffee planting there with much the same results, and possibly for the same reasons. A more detailed account will be found in the chapters dealing with coffee production in the main producing countries. It was because the Nyasa coffee failed to give satisfactory results that the European planters in Uganda took to planting robusta coffee instead, and except for a small co-operative native production of Arabian coffee on the slopes of Mount Elgon, the native farmers have also been encouraged to grow robusta coffee.

Before German East Africa was captured by the British and became known as Tanganyika Territory, the Germans began planting Arabian coffee on the slopes of Kilimanjaro and Meru mountains in the Northern Province of that country. Seed was again supplied from mission stations, and from the plantations then existing in Kenya, so the strain for the most part was that of the bourbon variety. Shortly before World War I, however, seed of a strain known locally as the 'Menado' strain was imported from Java, and this was planted largely on the younger estates. During the same period the natives of Bukoba district, west of Lake Victoria, were encouraged to start planting robusta coffee for export purposes.

Many legendary stories have been omitted in this early history of the use of coffee—of its cultivation for the first time in various countries, and of its movement about the world. From the time its cultivation assumed the status of an industry in any country, the history of coffee enters the field of economics and trade, or is of greater interest to include in the chapters on the methods of growing and preparing coffee in the countries concerned. One thing this chapter endeavours to imply is that two strains of coffee moved about the world from the very beginning, to wit the type species which we must call *Coffea arabica* L. var. *arabica* and also *Coffea arabica* L. var. *bourbon*.

It must be admitted right from the start that there are a number of other distinctive forms of Arabian coffee in cultivation. All of them have arisen as mutations in cultivated fields in later years except one, so there remains the so-called Mocha, Moka or Mokha variety to account for. In regard to this it is advisable to study the chapter on cytology and genetics, because the 'Mocha' variety is also shown to be a mutation. All the other mutating forms, along with the 'Mocha' variety, are stated to have been derived from either the species type var. *arabica*, or the var. *bourbon*.

It is trite to assume that, provided the environment does not inhibit them,

all these mutations may arise and be found among the indigenous growths of Arabian coffee in the Abyssinian mountains. Furthermore, there must have been a better chance for a mutation to survive when once the coffee had been taken into cultivation in the Yemen territory of Arabia. 'Mocha' coffee, as will be seen, has a smaller growth, a smaller leaf and a smaller bean, and it may have persisted in later years in Arabia because it suited its environment and the treatment it was given.

It must also be remembered that all coffee exported from Arabia through the coastal town of Mocha, was labelled 'Mocha coffee', and we know that it gave rise to the two chief strains in the plantations of the world. Perhaps some of the small seeded Arabian coffee from the Yemen hills is not in truth Mocha coffee at all, as we know it genetically. Instead the small seeds and their special flavour may be developed on account of the climate, the type of soil, or the primitive treatment it receives in this little-known region of Arabia.

Much of the Mocha coffee trade is carried out by merchants of alien races in the Red Sea ports, for instance at Aden, and here there is another tale to tell. Coffee is certainly carried down from the Yemen hills, as it has been throughout the ages, but it is blended, in other words mixed with other coffees imported from Abyssinia, from East African ports, and elsewhere. Much of the coffee imported from East Africa is of inferior quality and indeed a great deal of it has been imported in the form of dried, light, half-empty berries, known as 'Buni' coffee. The 'Buni' is hulled, and the peelings sold to the poorer Arabs of the hinterland, and from this they make their coffee, since they do not normally brew their coffee from roasted beans. The small impoverished beans within the hulls are picked over and sorted and mixed with the other coffees to increase the bulk and assume the general designation of Mocha coffee.

Chapter II

THE ECONOMIC SPECIES OF COFFEE

1. THE ARABIAN AND ROBUSTA COFFEES

THE GENUS COFFEA

THE family *Rubiaceae*, to which the genus *Coffea* belongs, requires a great deal of overhauling and reclassification by competent botanists. The genus *Coffea* itself is very confused, and no matter what was said, it would be impossible to obtain agreement, as yet, among those who have studied the subject. After a careful examination of the dried material in the Kew Herbarium and the British Museum, and also of the relevant literature, one can only follow the trend of opinion and state the facts as they are known in relation to modern international nomenclature.

Chenney[1] mentions forty species, and lists nineteen economic species of coffee with their varieties, among which are those widely cultivated, and others used to some extent in the localities in which they are indigenous. Other botanists disagree with his list and add to it, or alter it and reduce some of his species to mere varieties. Opinions are hardening to the belief that many are not distinct, but mere forms, so greatly do some of the species vary and merge into each other in all their characters.[2]

Species which are, at present, of no economic value, are not included in this book. They must remain of academic interest until geneticists require to explore their value for the possible transference of genes giving immunity to disease, or drought resistance, or some other desired quality that may be hidden among them. In these modern times it is unwise to disregard a species merely because it has no apparent value today.

The genus ranges from slender sprawling plants, that closely resemble jasmine, through all sizes of shrubs, to robust trees with clean trunks and spreading heads, growing thirty and sixty feet tall. Sometimes a single species will vary so greatly that in some forms it is a shrub, and in others it grows into a tree.

The author ventures to place the most widely grown coffees under four species in order of their importance to commerce: 1. *Coffea arabica* Linn., 2. *C. canephora* Pierre ex Froehner, 3. *C. liberica* Bull ex Hiern, and 4. *C. excelsa* A. Chev. *C. robusta* Linden might then become a variety or form of *C. canephora*, with which Chevalier[3] and others agree.[12] Chevalier, however, makes *C. excelsa* one of several races or forms of *C. dewevrei* De Wild.

These four species and their varieties and forms will be treated as exhaustively as possible in this book, whereas the other so-called economic species will only be mentioned in this chapter, since they are used locally, or are found in botanic gardens and do not enter trade.

Since most of the varieties known today (1) arose spontaneously in cultivated fields (2) were mutants and forms selected by growers and propagated for commercial purposes (3) were found by geneticists among cultivated coffee and separated as varieties for the purpose of genetical record

or (4) were deliberately selected, hybridized and bred in a state of cultivation, these will not appear in this chapter, but will be listed in Chapter III as cultivated varieties, i.e., cultivars.

ARABIAN COFFEE

Coffea arabica Linn.

Antoine de Jussieu called Arabian coffee a jasmine in 1713, naming it *Jasminum arabicum laurifolia.*[9] He sketched a flowering branch with exactitude, *see* Plate I. Dr. James Douglas also called the species a jasmine in his monograph of 1727,[7] and a specimen collected by him (No. 330), dated 1728, is to be found in the British Museum named *Jasminum Arabicum.* It was not until 1753, after Linnaeus had placed the genus *Coffea* within his classification, that the species became known as *Coffea arabica.*[2]

The general description is *C. arabica* Linn.; L. Sp. Pl. p. 172 (1753); Hiern in F.T.A. 3, p. 180 (1877); Holl. 3, p. 361 (1915); Chev. Bot. 335 (1920). A glabrous glossy-leaved shrub or small tree. Leaves relatively small but varying in breadth, averaging 12–15 cm. long and about 6 cm. broad, oval or elliptical, acuminate, shortly acute at base, sometimes somewhat undulated, evergreen. Flowers fragrant, white or creamy, subsessile or very shortly pedicellate, several in each leaf axil, 2–9 or more together in very short axillary or lateral bracteolate clusters; bracteoles ovate, the inner ones connate at the base of the pedicels, falling short of the shallow sub-truncate or obtusely 5-denticulate calyx-limb. Corolla 5-lobed, lobes oval, obtuse or mucronulate, equalling or exceeding the tube, spreading. Anthers rather shorter than the corolla-lobes, wholly exserted, fixed rather below the middle to the filaments which are about half as long. Disk glabrous. Style about equalling the unexpanded flower, bifid, lobes linear, narrower towards the tip. Berry oblong-ellipsoid, about 1·5 cm. long, at first green, then red, and at length blue-black. Seeds varying in size from 8·5 to 12·7 mm. long. Syn. *C. vulgaris* Moench; *C. laurifolia* Salisb.

The species is indigenous in Abyssinia, and some say that it is indigenous in parts of Arabia,[8] though it is more likely to have escaped from early cultivated fields in this latter country. It has been taken into cultivation throughout the tropics, and wherever else it is said to be wild it is either an escape, a faulty determination, or possibly a hybrid between other species which has assumed the form, and many of the characteristics, of *Coffea arabica* L. Herbarium specimens in the British Museum labelled *C. arabica* L. indicate that the species is indigenous, for instance, in fringing forests of Portuguese Angola, but these specimens have doubtless been collected from escapes, or they are natural hybrids between *C. liberica* Bull ex Hiern, and *C. canephora* Pierre ex Froehner, or *C. congensis* Froehner, which vary enormously and often appear to merge into each other through intermediate forms. *C. welwitschii* Pierre ex De Wild. has also been confused with *C. arabica* L. in Angola and along the West Coast. This, if it is a distinct species, is undoubtedly indigenous in the secondary forests where it is found, and the forms with smaller leaves appear to resemble Arabian coffee. Chevalier believes it to be a form of *C. canephora.*[2]

The seeds of the ripe fruits of *Coffea arabica* L. have a sweet mucilaginous covering attractive to birds and to small animals, so they are readily distributed for many miles from cultivated areas into forest situations where they

germinate and form growths that appear wild. The author has seen collections of coffee seeds on the ground obviously vomited by animals and has been told by the local inhabitants that jackals were responsible.

In Abyssinia, *Coffea arabica* L. is found mostly in the southern mountains between latitudes 7 and 9 degrees N. among fringing forest growths, and along the banks of streams at altitudes of between 4,500 and 6,500 feet, often along the upper reaches of the streams which feed the river that flows into Lake Rudolf.[2 3] Even in its wild habitat the species is said to be variable in many of its characters, and doubtless some of these varying forms found their way to Arabia and thence to the plantations of the world. When coffee seeds were taken from Arabia it sometimes happened that only one or two plants lived to become the progenitors of new plantation industries, and this might account for the difference in some of the strains of Arabian coffee that are now cultivated.

Throughout the years during which Arabian coffee has been in cultivation it has been planted in private and botanic gardens in close proximity to other species, and there are many accounts of resulting seedlings showing intermediate forms. Varieties of Arabian coffee have arisen from the natural indigenous material as mutants in cultivated fields. Mutations are frequent in large plantations of Arabian coffee, and the author has seen plants with narrow leaves and many of the characters of *Coffea stenophylla* G. Don., growing from seed amidst normal types of *C. arabica* in Uganda and Tanganyika. Plants have also been noted with leaves in threes, and fruits three-seeded, instead of the normal paired leaves and fruits with two carpels; also plants with leaves distinctly reddish in colour. Beyond differences in the shapes and sizes of the leaves and flowers, Arabian coffee has four main growth characters; the laterals either grow almost horizontally from the main stem and eventually droop, or they grow stiffly upwards at an angle of 45°, and as they grow older are pulled downwards at the tips by the weight of the fruit. The young leaves of both forms may be green or bronzed, and this would appear to be a character that can become fixed.

Arabian coffee varies again on account of environmental influences. In localities where temperatures are high, the air humid, and the rainfall unevenly distributed throughout the year, the leaves may be a pale green and comparatively small. At optimal temperatures the leaves are larger and growth is more robust, the leaves being a healthy and darker green; almost a dark blue-green after a spell of dry weather. In forests, or wherever a plant is grown under shade, the leaves may be much larger and less leathery, so that unless he is cognizant of all these facts it is easy for a botanist to be nonplussed when examining dried material in the world's herbaria. The influence of climate, shade, or soil, may make a dried specimen appear as though it came from some intermediate form.

The forms of Coffea arabica L.

Botanical descriptions in floras seldom suffice to cover all the varieties and forms of a species, and this is especially the case when a whole genus has been allowed to get into a state of confusion. Chenney[1] lists nine varieties of *C. arabica*, of which only two may be called botanical varieties; one is almost certainly a form of *C. canephora*, two would appear to be separate species, and the others are mutants or forms of *C. arabica* arising in cultivated fields and hence cultivated varieties. The two botanical varieties are 1. *Coffea*

arabica L. var. *arabica* (syn. var. *typica* Cramer), and 2. *Coffea arabica* L. var. *bourbon* (B. Rodr.) Choussy. Geneticists have shown that all the cultivated varieties are mutants and forms which have been derived from these two.

Two coffees which Chenney lists as varieties of *C. arabica*, Chevalier lists as separate species. If they are species indigenous in Madagascar, the Comoro Isles, and Réunion, then they resemble *C. arabica* L. If they are varieties, then they must have arisen as mutations in cultivated fields, or as hybrids between escapes from cultivation on the one hand, and other species which are truly indigenous. The first of these is *C. humblotiana* Baill., of which there is a specimen in the Kew herbarium, and the second is *C. rhachiformis* Baill.

The French took coffee to Réunion Island in the years 1717-18, and natives introduced coffee to Madagascar from Mozambique about the same time. Among the native introductions may have been seeds of Ibo coffee. A little later the French made other introductions of coffee to Réunion and Madagascar, doubtless interesting themselves in testing more forms and species as they became known, so that the two coffees in question may have appeared in cultivated plantations by hybridization. A good deal of planting material must have been exchanged between Madagascar, the Comoro islands and Réunion in those early days, as the coffee-drinking habit developed in Europe, and many of these movements would not have been recorded.

Chevalier rates *C. humblotiana* Baill., as a separate species occurring in the Mascarene Islands region. It was actually discovered in the Comoro islands, and forms a small tree with rather large fruits turning black when ripe and having longitudinal grooves where the carpels unite. The seeds are reported to be devoid of caffeine[1] though they supply a coffee said to be of good quality by the inhabitants of the Comoro islands.

Coffea rhachiformis Baill. is given as *C. arabica* L. var. *rhachiformis* (Baill.) Froehner, in Chenney's monograph on coffee, while Chevalier later restores it to specific rank. This species (or form) also was discovered in the Comoro islands about the time when *C. humblotiana* was found. The flowers are sessile and very small, as also are the fruits which are borne in ones and twos and turn red when ripe. The species has been cultivated to a small extent, and the liquor derived from the roasted beans is said to resemble that from Mocha coffee.

Though Chenney and others have listed *Coffea arabica* L. var. *stuhlmannii* Warb., as a variety of Arabian coffee, it is now generally accepted as a form of *C. canephora* Pierre ex Froehner, [syn. *C. bukobensis* Zimmerm.]. Coffee varies enormously in the Bukoba district where the author resided for five years. During the last forty years or more the inhabitants have cultivated a considerable quantity of Arabian coffee, which is exported under the trade designation of 'Plantation Coffee', and the trees are planted haphazard among the 'robusta' coffee in the banana groves. Close planting has been the rule, leading to a natural hybridization between the two species.

Another very doubtful case is that of *Coffea arabica* L. var. *intermedia*, Froehner. Chenney speaks of it as growing wild in the Lake region of Africa, and it is said to have been found growing on the Ruwenzori Mountain range in places where *C. canephora* is indigenous and where *C. eugenioides* S. Moore, is also common and can hardly be distinguished at times from *C. arabica*.[4] This so-called variety of Arabian coffee is more likely to be a form

of *C. canephora*, or a hybrid. It was apparently discovered before Arabian coffee was cultivated by the inhabitants of Uganda.

The origin of *C. arabica* L. var. *leucocarpa* Hiern, is shrouded in mystery. It was apparently found in Sierra Leone, and was first described from one of Th. Vogel's dried specimens dated June 1841. Though the plant has been cultivated in Upper Guinea, the product has no commercial value, since the fruits are only the size of a small pea and white in colour when ripe. It is distinctive in so many ways that the author joins with others in thinking that it should be regarded as a distinct species.[1]

Three of the forms listed for many years as varieties appear to have arisen as mutations in cultivated fields. They are listed in this book as cultivated varieties. That which has been called *C. arabica* L., var. *maragogipe* Hort., arose as a sudden mutation in the province of Bahia, Brazil, and was first discovered in 1870 and propagated by Crisogono José Fernandez near the township of Maragogipe. A Mr. Thomas Christy sent seeds to Kew in 1883 from which plants were raised and grown in the palm house. Afterwards it was cultivated in most tropical countries, becoming a vogue in certain localities until it proved uncertain in yield. The plant might be described as a gigantic form of the common Arabian coffee. Growth is a little faster, and for this reason the trees mature earlier; they have longer internodes, larger leaves, and larger fruits containing elongated and large seeds. After the tree has borne its first heavy crop it is difficult to keep it shapely, and subsequent yields prove disappointing.

The second of these has been recorded as *C. arabica* L., var. *amarella* Hort., ex Froehner. Amarella coffee is more of a rarity and a curiosity because it bears yellow fruits. It was first discovered in Botucatú, São Paulo, Brazil, in 1871. Since then it has been cultivated to a small extent in Brazil, Central America and India. Other common names used are Botucatú Coffee and Golden Drop Coffee. The plant develops into a small tree, perhaps a little smaller than the common Arabian coffee, and the fruit is said to have a remarkably high caffeine content.[1]

Lastly the third has been given as *C. arabica* L., var. *angustifolia* Miq. It bears long narrow leaves which are very cuneate, and very acuminate, but they are broader in the distal half, which has led botanists to call them spatulate. The variety is based on *C. angustifolia* Roxb., and it appeared in the province of Menado in the Celebes. It is also known in Brazil plantations as a mutant, and it has no real commercial value in comparison with the better known cultivated forms. It is not the 'Menado' coffee which is so well known in the Northern Province of Tanganyika. The variety listed as *Coffea arabica* L., var. *straminea* Miq. [syn. *C. sundana* Miq], is said to be found in Sumatra, Java, and the Celebes, and sometimes cultivated. It would appear to be very close to *angustifolia*.

The two original varieties of C. arabica L.

Coffea arabica L., var. *arabica* [syn. var. *typica* Cramer] is the type described by Linnaeus. It appears to have been, and still is, the most common and primitive form of *C. arabica* L., first taken into cultivation by the Dutch in the East Indies, and then in many other parts of the world, including Ceylon. The plant given by the Dutch burgomaster to King Louis XIV of France, which was later taken to Martinique, and is thought by many to have been the ancestor of most of the Brazilian Arabian coffee, may well have been

of this variety. Undoubtedly it became the common variety in Brazil, and is still largely in cultivation today. It is the variety known as 'Nyasa' coffee, which was grown extensively in Nyasaland and later in Uganda. It has been said that in Brazil it is the variety having the strongest stamina, and yet, experience in Nyasaland and Uganda showed it to be the most susceptible to diseases, to die-back, and all manner of insect pests, probably because the environmental conditions were not ideal. The leaf-spot disease has not appeared in Brazil, and the climate in the coffee-growing area is generally much cooler. The variety is one that will quickly grow into a sturdy tree if it is not topped; the main branches grow only slightly upwards from the trunk, and soon become horizontal, and then pendulous as the secondary branches are formed and bear a heavy load of fruit. The leaves are elliptical, both acuminate and cuneate, and the twigs with their young leaves are generally bronze-tipped.

Coffea arabica L., var. *bourbon* (B. Rodr.) Choussy., is, according to Krug and Carvalho, a recessive mutant, and one from which a number of cultivated varieties have been derived such as their var. *caturra*, var. *semperflorens*, and var. *laurina*. The var. *bourbon* is that which the French propagated and favoured in their island of Réunion, and which was raised from seed directly imported from Arabia very soon after the Dutch sent their first expedition to obtain seed. Planting material was undoubtedly taken in later years to their West Indian possessions, from which it was spread to Central and South America. It is now sought after by planters in Brazil, for it is said to give high yields. In East Africa it is said to be weaker in stamina than the var. *arabica*, but to have better liquoring qualities. The bourbon variety is one that will grow into a somewhat slender tree if not topped. The main branches grow stiffly upwards at first at an angle of about 45° from the trunk, but they ultimately curve horizontally and have their tips pulled downwards by the weight of fruit. The leaves are broader than the var. *arabica*, and the bronze colouring is generally absent from the young leaves.

ROBUSTA COFFEE

Coffea canephora Pierre ex Froehner

Systematic botanists will not now accept the name *Coffea robusta* Linden, for anything more than a form or variety of *C. canephora* Pierre ex Froehner, and this at once creates a difficulty, because growers and trade the world over have grown accustomed to use the term 'robusta' to cover all the varying forms of, and the ultimate product of *C. canephora*. *Coffea robusta*, as understood by various authors, seems to include all the forms now referred to as *C. canephora*, and it is necessary to examine the names from the point of view of the type method. Thus *Coffea robusta* Linden, must be regarded as synonymous with, or as a variety of *C. canephora* Pierre ex Froehner.

Botanists have admitted that a study of herbarium specimens does not permit them to separate the distinctive forms from those that fluctuate in character and are therefore of little taxonomic interest, so the author must be forgiven if he, who is not a systematic botanist, keeps as warily as possible to the straight and narrow path. It is even doubtful whether many of the named varieties could be separated in the field without confusion and disagreement, since they all have so many intermediate forms merging one into the other.

Undoubtedly *C. robusta* Linden, is a form of, or synonymous with *C. canephora* Pierre ex Froehner, but so are others it seems, such as *C. laurentii* De Wild., *C. maclaudii* A. Chev., *C. arabica* L. var. *stuhlmannii* Warb., *C. bukobensis* Zimmerm., and *C. welwitschii* Pierre ex De Wild., also *C. ugandae* Cramer.[2 12] The species is described, in general, as follows: *C. canephora* Pierre ex Froehner in Notizbl. Berlin, Bot. Gart. Ber.1, p. 237 (1897). *See also C. robusta* Linden, Cat. Pl. Econ. 64. (1900).—A glabrous shrub or tree, with large broad leaves often assuming a corrugated or undulating appearance, oblong elliptic, shortly acuminate, rounded or broadly cuneate at base, 15-30 cm. long and 5-15 cm. broad; midrib flat above, prominent below, lateral nerves 8-13 pairs; strong petiole 8-20 mm. long; stipules interpetiolar, broadly triangular, long-mucronate, connate at base, semi-persistent. Flowers white, sometimes slightly diffused with pink, in two axillary clusters, sessile, with or without leafy bracts. Corolla 5-7 lobed, tube much or only a little shorter than the lobes. Stamens and style well exserted. Berries broadly ellipsoid, about 8-16 mm. striate when dry. The plant is very variable in the wild state.

Coffea canephora Pierre ex Froehner, is indigenous in African equatorial forests stretching from the west coast to Uganda and the Southern Sudan, and possibly into Western Abyssinia wherever there is sufficient rainfall, a favourable range of temperatures and high humidity. It borders rivers, fringes forests and is found in forest glades sometimes in dense shade. It is indigenous in French, Belgian, Portuguese, and British territories in West Africa, chiefly between latitudes of 10° N. and 10° S. at altitudes from sea level up to 3,500 feet.

It was found in a state of semi-cultivation in the villages of a number of native tribes when the first explorers reached Africa. For instance, when Grant and Speke separately visited Uganda, they both found it used by the natives. Though a few of the trees discovered in the Uganda forests must owe their origin to human agency, and may be escapes from cultivation, old trees occur in such profusion in places where robusta coffee has not been cultivated, such as in the Kibale Forest of Toro District, that the species must be indigenous there.

Thomas[12] states that it is often abundant and frequently dominant in patches in the small-tree layer of the forest, where it is quite tree-like itself, since it grows 12 to 30 feet tall with a trunk up to 8 inches diameter, the habit depending on the density of the overhead shade. In open glades the branches spread from near ground level, whereas a more upright growth with a clean trunk is noticeable in dense shade. Thomas goes on to say that it is usual to find considerable variation among the wild coffee of any one forest, and that the forms in the separate forests show well-marked differences in their habit, and in the size and shape of their leaves and fruit.

So much is this the case that the two most distinctive forms which have been taken into cultivation in Uganda need quite different systems of pruning to control their shapes and yields. Even so, there are intermediate and merging forms between the two.

The forms of Coffea canephora Pierre ex Froehner

According to Thomas[12], Pierre listed and described in manuscript seven varieties of *C. canephora*, and mentioned one other. These were *kouilouensis*, *hiernii*, *hinaultii*, *muniensis*, *oligoneura*, *trillesii*, *wildemannii*, and *opaca*, all

published by De Wildeman. A ninth is listed by Laurent according to Chevalier[2] as *sankuruensis* De Wild. None of these seems to have been distinctive except the first, and perhaps for this reason the other names have not persisted in literature or in commerce. To illustrate how each form can be sub-divided, Pierre splits *C. canephora* Pierre ex Froehner var. *kouilouensis* Pierre ex De Wild., into three, i.e. *grisea*, *flavescens*, and *latifolia*, which does nothing to unravel the tangle caused by the ease with which one variety merges into another through intermediate forms, and by the eagerness of some botanists to describe these as separate species and varieties.

The *kouilouensis* variety grows into a small tree bearing large elliptical leaves, and was discovered when French settlers went to French Equatorial Africa in 1880. They found it south of Loango between the Gabun and Congo rivers, chiefly at Kouilou, growing in the forests and along the banks of rivers. Curiously enough the variety was discovered and cultivated before Pierre described *C. canephora.*

Kouilou coffee was noticed by other travellers, and about 1886 Wisser established a small plantation in the region of the Loeme. In later years a Dutch Society and a man by the name of F. Sargos made larger plantations in this neighbourhood. It was from here that seed was taken to the Dutch East Indies under the name of 'Kouilou' coffee,[2] giving rise to a misquotation in some writings, and the shortened version '*Coffea quillou*'. Thomas adds a footnote to his chapter on 'robusta' coffee[12] and says that the 'Nganda' form in Uganda corresponds to the 'Quillou' or 'Kouilou' in the Dutch East Indies, and that the Dutch describe the erect Uganda form as *C. ugandae*. It is later stated in the same chapter that imported Javan types mostly resembled the No. 9 selection in Uganda, which is the erect and tree-like type originally selected from the wild coffee of the Toro forest region!

Whether the name *Coffea ugandae* Cramer, applies to the form of *C. canephora* known as 'Nganda', is, therefore, questionable. The African growers of coffee in Uganda prefer the very distinctive 'Nganda' form, which tends to grow into a large dome-shaped shrub rather than a tree. As the plant grows it bends over with the weight of crop, and then suckers sprout from the bent portion of the stem. These in turn bend down and produce more suckers, so that a large shrub develops covering an area 20 to 30 feet in diameter, rather like a large rhododendron bush in shape. It is easy to understand how the progressive growths may be assisted by deliberately bending the branches down, and by thinning out the suckers as they sprout.

The leaves, also, are much smaller, and though the plant is obviously a form of *C. canephora*, it is sufficiently distinctive to have a varietal name. Nothing could be better than to give it the name *C. canephora* Pierre ex Froehner, var. *nganda*. It is therefore described as follows: '*Coffea canephora* var. *nganda* Haarer, var. nov., a *C. canephora* var. *canephora* statura minora, habitu hemisphaerico haud arboriformi latius ramosa, foliis saepe minoribus laevioribus differt. In Uganda indigena.'

Several species which are said to be synonymous may eventually be found to be forms of *C. canephora* Pierre ex Froehner, or, if they are sufficiently distinctive, they may be relegated to varietal rank. *C. arabica* var. *stuhlmannii*, and *C. bukobensis* appear to be very similar to each other and merely small-leafed forms of *C. canephora* found chiefly in the Bukoba District of N.W. Tanganyika. *C. laurentii* De Wild., and *C. maclaudii* A. Chev., appear to have no real distinguishing features to make them either separate species, or even

distinct varieties. There remain *C. robusta* Linden, and *C. welwitschii* Pierre ex De Wild.

According to Chevalier it was not until shortly after 1897 when *C. canephora* became known under the general name of *C. robusta* Linden. In 1895 the species was discovered in the Congo basin by Emile Laurent, where it was cultivated by a few natives and Arabs, and was also obviously indigenous. He identified the species correctly in 1898 as *C. canephora*, but two years later De Wildman believed it to be a new species and named it *C. laurentii*.

In 1900 Linden called the material from the Congo basin *Coffea robusta*, and figured it in his catalogue of *New Plants of Horticultural Interest in the Colonies*. Later the use of the name 'robusta' became prevalent in Java, and thence throughout the world. It is now obvious that the older name *C. canephora* takes precedence, in spite of the fact that the name 'robusta' is used by planters and the coffee trade for all the forms of *C. canephora* and their products. It is not even a true variety of *C. canephora*, and though common usage will undoubtedly prevail, it would seem an error to list the plant as a separate species under the name *C. robusta* Linden, as some of the more recent floras still do.[8]

Pierre recognized *C. welwitschii* Pierre ex De Wild., as a species intermediate between *C. arabica* and *C. canephora*, since it has smaller leaves, and it has often been referred to erroneously as Arabian coffee. It is indigenous principally in Angola, and does not occur beyond the western equatorial region of Africa. It has given rise to many reports that Arabian coffee is indigenous there, but Chevalier and others are agreed that it is in the *C. canephora* group. A note on a specimen sheet in the British Museum gives it as *Coffea canephora* Pierre, var. *welwitschii* (Pierre) A. Chev.

So greatly does *C. canephora* vary, and so generally alike are the descriptions of *C. congensis* and *C. welwitschii*, that one ventures to suggest that even *C. congensis* may ultimately be considered a form of *C. canephora*. If so, it may be sufficiently distinctive to be a variety, or it may be considered a natural hybrid. De Wildman has described two varieties of it: var. *charlotti* Pierre ex De Wild., and var. *subsessilis* De Wild., but Chenney questions whether these can be maintained.[1]

Some of the forms of *C. congensis* resemble Arabian coffee, and for this reason there have been reports that Arabian coffee might be indigenous in West and Central Equatorial Africa. The plant is found wild in the Belgian Congo along the tributaries of the Congo River and at Stanley Falls, at altitudes of 1,000 to 1,500 feet. It is often found in the areas of seasonal inundation, on islands of raised land that escape flooding. Chenney records it as a species found in the Lake Chad region, but Chevalier dismisses this as a mistake.[1,2] The plant has a somewhat slender growth, and it differs because its flowers are yellowish, and fissured. The fruits of the *subsessilis* form are elongated, but in other respects they resemble those of *C. canephora* in that they are furrowed where the carpels join. The plant has been cultivated, but its yield is said to be poor, and together with the fact that it varies in form, these are indications that the plant may be a hybrid.

Dalziel[6] lists *Coffea brevipes* Hiern, [syn. *C. staudtii* Froehner] as nearly related to *C. congensis*, and *C. arabica*. Chevalier[2] declares it to be a dwarf form of *C. congensis* and advises its experimental cultivation. The plant was discovered by Gustav Mann in 1862 and was described by Hiern in 1880. It

is indigenous in the French Cameroons near the sea coast, and also in the Cameroon Mountains at altitudes of 2,000-3,250 feet growing in dense forest. It is a glabrous miniature form that grows into a shrub only a few feet tall.

The varieties of Coffea canephora Pierre ex Froehner.

It will be seen in the chapter on genetics that *C. canephora* is usually self-sterile, and it must therefore be cross-pollinated to bear viable seed. This makes it very difficult to separate most of the forms and call any of them distinct varieties. There are strains, however, with characters which appear dominant, giving, for instance, a form with such a strong upright growth that the seedlings develop into trees. This form might well have given rise to the name *C. robusta*, and if this is the case then it might be considered as conforming to the type of the species and be called *C. canephora* var. *canephora.*

Then there is the other strain of a more sprawling habit, which grows into a large dome-shaped bush, i.e., the 'Nganda' strain, which is now named *Coffea canephora* var. *nganda* Haarer, [syn. *Coffea kouilouensis* Pierre ex De Wild.].

Except for a dwarf, and more shrubby form, many of the so-called varieties of *C. canephora* may be varietal hybrids, linking the two common forms with merging characters, and this is as much as the author is prepared to say.

2. The Remaining Economic Species

Although the Arabian and 'robusta' coffees provide most of the world's trade in coffee, the Liberian and 'excelsa' coffees have been taken to most countries in the tropics where they are grown in botanical gardens or small patches. Fair quantities are exported from West Africa and used as 'filler' material, since the liquoring qualities are not usually of a high standard.

These two coffees of lesser economic importance have also been used for hybridization and for grafting, and since they vary a great deal in form, and also in the size of the beans and their liquoring qualities, it is possible that selections will prove of great value as they become known. Liberian coffee has very large fruits and beans, and the trees grow vigorously in the hotter and more steamy regions of the tropics, where Arabian coffee would not grow well and would probably suffer from all manner of diseases and pests. *Coffea excelsa* is a large and virile tree which, alone of all the economic coffees, is adapted to the hotter semi-arid country of the West African hinterland. These attributes may be worth remembering in future, since 'excelsa' coffee would need little care when once it had grown into a sizeable tree. There would be little cultivating or weeding to do, and no pruning. All that would be necessary in the beginning would be the improvement of the liquoring qualities by selection or hybridization, to enable the production of a marketable coffee in environments unsuited to other species.

Beyond these two species there are a number of others which will be dealt with as far as possible in order of their importance. These are rarely cultivated except in village compounds in the countries in which they grow wild, since the berries are usually collected from forest growths.

LIBERIAN COFFEE

Coffea liberica Bull ex Hiern.

Liberian coffee is distinguished from others by the leathery gloss of its large leaves, by the fact that it grows into a large shrub or tree from fifteen to forty feet tall, and by its large berries. Confusion exists again in regard to this species because the plant varies such a great deal in the shape of its leaves, in its growth characters, and in the size of its fruit, though it must be maintained that even the smallest-fruited forms have fruits and seeds larger than any other kind.

The species appears to merge into and to have the same habit as *C. macrochlamys* K. Schum., except that the latter has flowers with much larger calyx involucral bracts.[8] The botanical description of *C. liberica* is as follows:

Coffea liberica Bull ex Hiern; Hiern in *Trans. Linn. Soc. Lond. Ser*; 2, I, *p.* 171, t.24 (1876); Stapf, 613; Holl.3: 364; Chev. Bot. 336. A glabrous shrub or tree. Leaves rather large, shining; blade broadly cuneate at base, broadly elliptic-obovate, shortly acuminate, somewhat undulated, thinly coriaceous, about 20 cm. long and 10 cm. broad: lateral nerves of leaves 7-10 pairs, with pits in the axils of the nerves; petiole 10-16 mm. long; stipules broadly ovate, apiculate, connate at base, shorter than the petiole, 3-4 mm. long. Flowers white, 7-6 merous, subsessile, clustered several together, axillary, about 3·5 cm. long; bracteoles connate, calyculate, depresso-deltoid, subtruncate, all shorter than the subtruncate calyx; sometimes one oval bracteole is produced above the others. Calyx-limb annular, very short. Corolla lobes 6-8, lobes oval, obtuse, about as long as the tube, spreading. Anthers 6-7, wholly exserted, 1·27 cm. long; filaments 6·4 mm. Style exserted, bifid. Berry oval, about 2·5 cm. long, at first red then black when ripe, wrinkled when dry. Seed 1·27 cm., or rather more. Syn. *C. abeokutae*, Cramer, *C. klainei* Pierre ex De Wild., [*C. arabica* (non Linn.)—Benth. in Hook. Nig. Fl. (1849) 413.]

The species is indigenous in the neighbourhood of Monrovia in Liberia, and it has been spread since very early times by cultivation here and there, and by escapes from cultivation, seemingly growing wild in most countries along the west coast of Africa. Sir Joseph Hooker became aware of it in 1872 by which time it was in cultivation in the Gold Coast and Sierra Leone. In the same year plants were sent to Kew by Sir John Hennessy, who was the Governor of the West African settlements, but they did not survive the journey. Shortly afterwards a Mr. C. S. Salman, who was administering the Gold Coast in that year, secured seeds from the Rev. T. B. Freeman who had planted the species near Accra. Plants from these seeds were grown in India, and in the following year a Mr. Bull of Chelsea, London, imported living plants. He published a popular description of the species in his *List of New, Beautiful and Rare Plants*, and called it *Coffea liberica*. Hiern adopted the name when he described and sketched the plant in 1880.

More about its distribution and use in the world will be given in later chapters, but it can well be understood how this beautiful plant has found itself placed in many a botanical and ornamental garden in the tropics. Its large, dark-green and glossy leaves, tinged with pink when young, make a striking background for the large white star-like flowers, which, because they open at odd times throughout the seasons, bear fruits that are also in varying

By courtesy of Licenciado Don Juan Rebolledo Clement

Coffea arabica var. *bourbon* (B. Rodr.) Choussy, growing in Mexico. Note exuberant growth of laterals, the rather slender main stem and the flowering on young wood, i.e. environmental effects.

PLATE II

By courtesy of the Royal Institute for the Tropics, Amsterdam

Coffea canephora Pierre ex Froehner. Branches in full flower. Note the corrugations of the leaves

PLATE III

By courtesy of World Crops

(*a*) *Coffea canephora* (robusta) growing in Uganda

(*b*) *Coffea canephora* Pierre ex Froehner. Fruiting branches of a tree in Java. Note the corrugated leaves and the manner in which the fruits are borne in whorls

By courtesy of the Royal Institute for the Tropics, Amsterdam

PLATE IV

By courtesy of Dr. J. D. Tothill and the Oxford University Press

(*a*) Mature trees of *Coffea canephora*, spreading form in Uganda, now named var. *nganda*

(*b*) Mature trees of *Coffea canephora*, erect form in Uganda

By courtesy of Dr. J. D. Tothill and the Oxford University Press

PLATE V

By courtesy of Dr J D Tothill and the Oxford University Press

(*a*) Young trees of *Coffea canephora*, Pierre ex Froehner, with spreading habit of growth; now named var *nganda*

(*b*) Young trees of *Coffea canephora* Pierre ex Froehner with upright habit of growth, in Uganda the No 9 selection

By courtesy of Dr J D Tothill and the Oxford University Press

PLATE VI

By courtesy of the Royal Institute for the Tropics, Amsterdam

Coffea canephora Pierre ex Froehner Quillou coffee in Java growing under shade of *Erythrina* sp Said to be like the *nganda* variety of Uganda

PLATE VII

stages of growth. There are small green berries, yellow-red ones and red-ripe fruits on the branches at the same time, and a handsomer, more ornamental shrub or tree could not be found.

The forms of Coffea liberica Bull ex Hiern

Where Liberian coffee has been cultivated on the Ivory Coast, a small-fruited form has been given the varietal name of *ivorensis*, a larger-fruited form is called *liberiensis*, and an intermediate form is listed as *indeniensis*. This last form is said to be the one preferred for cultivation. According to Rochette[11] the smaller-fruited kind is the form usually found wild on the Ivory Coast, but Court[5] mentions a small-fruited Liberian coffee on the lower Ivory Coast as a hybrid between *C. liberica* and 'plateau coffee'. Hence the deeper we delve, and the more forms and varieties we list from among the literature, the more confusion we find in the genus *Coffea* and its main groups. Some botanists group *C. macrochlamys* K. Schum., with *C. liberica* Bull ex Hiern; others, such as Chevalier, group it with *C. excelsa* A. Chev.

The selections on the Ivory Coast are not, perhaps, sufficiently distinctive to be given varietal names. They are probably mere forms of *C. liberica*, and hybridization is suspected because the plant readily hybridizes with *C. arabica*, and gives, as it is said to have done along the east coast of Madagascar, hybrids which produce a superior quality of coffee. It may also have crossed with *C. dewevrei* of the 'excelsa' group, and with *C. canephora.*

Another so-called species, *C. klainei* Pierre ex De Wild., is placed by Chevalier[2] with *C. liberica* as a variety or a mutation. This is a large-fruited plant, and the author would like to sort out the tangle which exists, by placing the large-flowered large-fruited plants with *C. liberica*, and the small-flowered small-fruited plants having proper growth characteristics with *C. excelsa.* The numerous intermediate forms may be hybrids between the two.

Coffea klainei Pierre ex De Wild., was found by R. P. Klaine in the secondary forests near Libreville in the Gabun region of French Equatorial Africa. Chevalier thinks it is a mutation from *C. liberica*, which may have arisen among cultivated plants, and then escaped and become wild. It has remarkably large flowers and fruits, and since it is very near *C. liberica* in form it may well be a true variety in the Liberian coffee group.

EXCELSA COFFEE

Coffea excelsa A. Chev.

Although the species grows into quite a large tree, and is a gigantic race of coffee, the fruits are small and about the size of Arabian coffee. It was discovered in the region of Lake Chad, and it grows abundantly among other forest trees to the east of the Chari or Shari River, and in the southern regions of the Sudan. Hence it is sometimes called Shari coffee. It is not found in areas subject to inundation, and the tree appears to be adapted to the more arid and semi-arid regions of West Central Africa. The description of the species is given as follows:

C. excelsa A. Chev., Rev. Cult. Col., 10. pp. 258-259, (1903). Tree with large leaves 20-50 feet and sometimes 65 feet tall, having greyish and longitudinally fissured bark. Leaves vary in shape but are more or less obovate–lanceolate, sometimes obovate-spatulate with short acumen at apex. Blades

18-28 cm. long, 9-12 cm. broad; lateral nerves 6-9 pairs. Flowers small, white or pinkish, fragrant, arranged in 1-5 clusters at each node, each cluster with 2-4 flowers persisting after shrivelling for a long while. Corolla 5-6 lobes, tubes 8-10 mm. long, much shorter than the lobes; lobes 10-12 mm. long by 6 mm. wide. Stamens coloured green, and style well exserted. Calyx greatly reduced or absent, shorter than the disk. Berries ovoid and a little compressed, 17-18 mm. long, 15 mm. broad. [Syn. *C. dybowskii* Pierre ex De Wild., *C. arnoldiana* De Wild., *C. sylvatica* A. Chev., *C. aruwimiensis* De Wild., *C. royauxii* De Wild., *C. zenkeri* Krause ex De Wild; *C. dewevrei* De Wild. var. ex A. Chev.]

The forms of Coffea excelsa A. Chev.

The plants collectively known to growers as 'Excelsa' coffee have been referred by taxonomists to a number of different species. *Coffea excelsa* is distinctive in its growth characters, and no departure from its tree-like habit can be accepted without suspecting a hybrid origin. It is noticeable that Chenney[1] in his monograph on coffee, makes no attempt to list or describe a variety of *Coffea excelsa.* The species may vary within itself in a way that is normal, and the attempts which have been made to arrange it racially into larger groups have gone too far. All the true *excelsa* forms should be big trees, and they may differ in leaf shape and size, fruit shape and size, as to whether the flowers fall when they wither, and in other small ways that are to be expected.

Beyond all the intermediate and merging forms are the type of *C. liberica* and *C. excelsa*, and these are sharply divided from each other by distinctive characters. It is easy to accept more and more diverging forms as varieties or species until confusion confronts the botanist.

Abeokuta coffee, i.e. *C. abeokutae* Cramer, is thought by some[11] to be a form of *C. liberica*, 'belonging to the group *C. excelsa* A. Chev.' which obviously also places all the *excelsa* forms in a group with *C. liberica.* Chevalier, however, argues that the varying forms of *excelsa* constitute a distinct group of their own. He brought all the forms of *excelsa* together as varieties of *C. macrochlamys.*[3] In a later publication, however, he changed his mind, and transferred *C. macrochlamys* to the genus *Tricalysia*, thereby excluding it from the genus *Coffea.*[4] He then adopted *C. dewevrei* as the type of the group which included a number of varieties, among which was *C. excelsa*. If *C. macrochlamys* is indeed a coffee then it is said to have characters which tend to make it an intermediate form,[8] 'having the habit of *C. liberica.*'

Chevalier speaks of the older grouping of species under *C. liberica*, and points to the differences in the size of the flowers and fruits, which tend to separate *C. macrochlamys* from *C. liberica* and bring it nearer to *C. excelsa.* He says that these species have numerous forms still badly defined, many of which have not yet been described. Many, he says, do not grow true to the parent forms from seed.

According to Chevalier's more recent work,[4] *C. excelsa* is not a separate species but merely a variety of *C. dewevrei* De Wild., along with five other varieties which he considers more or less stable. He names these (*a*) var. *neo-arnoldiana* Chev. (Forma 1), (*b*) var. *aruwimiensis* (Forma 2), thus dividing *C. arnoldiana* De Wild. into two forms; (*c*) var. *dybowskii* (Pierre) Chev., (*d*) var. *sylvatica* Chev., and (*e*) var. *ituriensis* Chev.

The so-called species *C. arnoldiana* De Wild., or 'Kisantu Coffee', men-

tioned by Chevalier as grouped with *C. excelsa*, has its origin at Kisantu in the Belgian Congo, where it is cultivated and described as a shrub that grows 20–40 feet tall. It tends to increase its size by sucker growth, and is not tree-like. It has large shiny leaves similar to those of *C. liberica*, somewhat small flowers, and fruits that vary in size and have a fibrous skin. There is every indication that it is a chance hybrid and unstable.

To revert to *C. abeokutae* Cramer, or 'Lagos Coffee', this is said to attain a growth of only ten to fourteen feet tall, because it branches considerably at an early age. Chevalier states that it is similar to 'Le Petit Indenie' of the Ivory Coast, which, under the name var. *indeniensis* is mentioned as a cultivated variety of *Coffea liberica* Bull. A number of forms of *C. liberica*, and its hybrids with *C. excelsa*, have been called 'Abeokuta Coffee' in Java.

The author can only have confidence in *C. excelsa* A. Chev., as the true Excelsa coffee, and this is the tree-like plant that grows to a considerable size in the semi-arid region near Lake Chad. He must leave the disentangling of all the so-called varieties and forms which merge into *C. liberica* to posterity, remembering that there is likely to be a further reclassification when the wild forms over a wide region of poorly travelled country have been closely studied.

SENEGAL COFFEE

Coffea stenophylla G. Don.

The more usual name for the product of *C. stenophylla*, is Highland Coffee, but the use of this term might cause confusion with Arabian coffee. It has been exported from French Guinea under the name of Rio Nunez, and from Senegal as Senegal coffee, the former name having also been given to other species of coffee along the West African coast. It has also been called Sierra Leone coffee, Upland coffee, Bush and Wild coffee. Though it is truly indigenous in Sierra Leone and the Lower French Guinea, it has been cultivated in patches in other West African countries, i.e. the Ivory Coast, and the Gold Coast, dating back to the early Portuguese adventurers.

For a description see F.T.A. 3:182; Holl. 3:367; and Chev. Bot. 337. The plant is a glabrous shrub or small tree which Chevalier reports as growing 14–20 feet tall, with a trunk 10–15 cm. thick. The leaves are small, narrow, acuminate and shining. Flowers are white, few in number, axillary, tube 20–30 mm., lobes 6–8 in number, 15 mm. long. The stamens and style are exserted. The fruits are blue-black when ripe, small, varying in shape from round to oval; seeds are about 8 mm. long. The tree almost resembles a mutation, or a small form of Arabian coffee with narrow leaves, and the quality of the product is good.

The plant grows wild in hilly country at altitudes from 1,300 to 2,000 feet as a small tree in cool and shady forests, or along river banks where the soil is of granitic origin and the rainfall is fairly heavy. It has been tried in various parts of the world but is considered to be of little economic value. Thomas[12] states that the beans are small and the crops are very light on Senegal coffee introduced into Uganda.

IBO COFFEE

Coffea ibo Froehner.

This species is, perhaps, a near relative or a form of *C. zanquebariae* Lour.,[2]

from which it differs by having thinner leaves and a larger number of flowers in each cluster. Chenney disagrees with the supposition that it is derived from *C. zanquebariae*, and says that this has not been confirmed by study,[1] but the two species are obviously very closely allied, and they are both found in east coast localities in Africa. *C. zanquebariae* is found indigenous on the Zanzibar coast, where it is known as Zanzibar coffee, and it is said to have been introduced into Mozambique by the Portuguese. *C. ibo*, is found at Mozambique and in the East African tropics. The botanical description is as follows:

Coffea ibo Froehner in Notizbl. Bot. Gart., Berlin, 1. 231, 234 (1897). A glabrous shrub with numerous rigid branches with a light-coloured and fissured bark, the flowers 2–6 in clusters at enlarged nodes tending to appear before the flushes of leaves. Leaves dull dark green above, lighter in colour below, 8–9·5 cm. long, 4–4·5 cm. wide, with new flushes breaking out among the flowers, each leaf ovate or obovate with short obtuse tip, and attenuated into the petiole; lateral veins 5–7 pairs. Flowers and young fruit appear together on the same branch. Corolla 6-partite, 2·4 cm. long; tube 0·9 cm., lobes flat, broadened, obtusely-lanceolate, 1·5 cm. long. Stamens and style exserted. Fruit 1 cm. long, 0·6 cm. broad, red when ripe, turning to brownish-black. Seeds flat or bead-like, narrowing at each end.

The name *Coffea zanquebariae* Lour. Fl. Cochinch. 145 (1790), takes precedence regarding its earlier recognition and description, and if ever the two species are considered to be the same then they must both be brought under this name. *C. zanquebariae* differs only in minor characters. It has chartaceous leaves, dark green above, lighter and glossy below, with little hairy tufts in the axils of the veins. It is listed[1] as synonymous with *Amazona africana* Spreng., and *Hexepta axillaris* Raf. Another Mozambique species, *Coffea racemosa* Lour., is also very close to both *C. zanquebariae* and *C. ibo*. If the Portuguese did introduce *C. zanquebariae* into Mozambique as Chenney says, then it is possible that a selected form which did well in cultivation established itself in Portuguese territory and was subsequently named *C. ibo*.

Chevalier[2] lists a coffee by the name of *C. schumanniana* Busse, as a near relative of *C. zanquebariae* and states that it is a small tree with drooping slender branches found by W. Busse growing in shady and humid places in the valley of the Rovuma river in the southern part of what is now Tanganyika Territory. The collector discovered the plant in 1900, and described it in 1902. The product of *C. ibo* was first marketed in south-east Tanganyika (then German East Africa) in 1893 and also on a small Portuguese island named Ibo, latitude 12° south, from which Ibo coffee derives its name. One wonders whether the mainland product originated in the Rovuma valley.

Specimens of Ibo coffee were sent to the Botanical Museum in Berlin, and though it was mentioned in 1895, it was not described until 1897. Ibo coffee has been confused by the settlers and local people with 'Inyambane' or 'Inhambane' coffee which is derived from another species.

The species *Coffea racemosa* Lour. is inserted here, not because the product is known as 'Ibo Coffee' but because it is rather close botanically to *C. zanquebariae* and *C. ibo*. *C. racemosa* grows into a small profusely branched shrub about four feet tall. It differs only slightly from the other two, the leaves bearing numerous tubercles or warts on their surfaces. The flowers are subterminal, in erect bracteate racemes. The fruits are subglobose, small, red and watery when ripe, having two hemispherical seeds. Chenney

By courtesy of the Royal Institute for the Tropics Amsterdam

Said to be excelsa coffee growing on an estate in Java under *Erythrina* shade Note the shrubby form of growth This may well be a form of Liberian coffee or a hybrid

PLATE VIII

By courtesy of the Royal Institute for the Tropics, Amsterdam

(*a*) A fruiting branch of *Coffea liberica* Bull ex Hiern

(*b*) Said to be flowers of excelsa coffee. They are rather large for excelsa coffee and may be a form of Liberian coffee

By courtesy of the Royal Institute for the Tropics, Amsterdam

PLATE IX

gives as synonyms, *Coffea ramosa* Roem. et Schult., *C. mozambicana* DC., *Rudgea racemosa* Spreng. and *Hexepta racemosa* Raf. It is apparently found only in the island of Mozambique, where it is said to be used locally by the inhabitants as a substitute for Arabian coffee.

INHAMBANE COFFEE

Coffea swynnertonii S. Moore

A photograph of this coffee—which, except for dried specimens, is all the author has seen—recalls to mind a small holly bush. Not that the leaves have spines, but they are small, and dark, and wavy, and they gleam darkly against the light-coloured bark of the branches.

The plant grows into a thickly branched shrub having an ash-grey and fissured bark which is viscid or resinous when young. For description see S. Moore in *Journ. Linn. Soc. Bot.* 40. p. 95. 1911. The leaves are small, oblong-lanceolate, obtuse, with a short attenuated petiole, and a blade thinly coriaceous, glabrous, 2·5–3·5 cm. long, 1–1·8 cm. broad with white microscopic punctures above; secondary veins arched and considerably recurved; stipules awl-shaped, widened at the base and rigid. Flowers 2–4, white, axillary. Corolla with a funnel-shaped tube 7 mm. long, lobes 8–9 narrow, ovate-oblong, obtuse, 9 mm. long. Stamens and style exserted. Fruits small, narrow, ovoid-oblong, 9 mm. long by 6·5 mm. broad.

The species was discovered in Gazaland, Portuguese East Africa, where it is found growing abundantly along the Juababa river at an altitude of about 1,000 feet.[1] Coffee prepared from the beans is used by the local settlers and said to be of excellent quality. If it were not for the small leaves and their shape, together with the smaller berries and seeds and other small differences, the plant might be mistaken for *C. stenophylla* G. Don. It is closely allied to the species *C. ligustroides* S. Moore, discovered in the same region and described in the same year.

CHIRINDA COFFEE

Coffea ligustroides S. Moore

This is not to be confused with a non-economic species named *C. ligustrifolia* Stapf, discovered in Sierra Leone. *Coffea ligustroides* was discovered by Mr. C. F. M. Swynnerton in the Chipete Forest, Gazaland, Portuguese East Africa, some time during 1905, and the species was described in 1911.[10] It forms the dominant undergrowth in this forest patch, at an altitude of 3,750 feet, and the crops are usually light, probably because the shade is so dense. The product is called Chirinda Coffee, and it is said to be used by the local inhabitants who apparently consider it an excellent substitute for Arabian coffee.

Chevalier[2] lists *C. ligustroides* as a form of *C. swynnertonii*, and they are undoubtedly very closely allied.

Coffea eugenioides S. Moore

The only reason for placing this species in this position in the chapter is that it is said to be variable, and the smaller-leafed forms may be confused with the Inhambane or Chirinda coffees. Moreover it is widespread in East Africa and may be found to overlap with the other species in parts of Central

Africa. Not long ago the plant was discovered growing wild in the Nandi forests of Kenya Colony and it was given the name *Coffea nandiensis* because it was thought to be a new species.

Since then the Kenya material has been confirmed as *C. eugenioides*, a species which has also been reported from the Usambara mountains in North Tanganyika, and is abundant in the Uganda forests. It has also been recorded in the Belgian Congo, and southern Sudan. One need go no further in describing this plant than to remark on its resemblance to a slender and smaller form of *Coffea arabica*, for which it has been mistaken when the larger-leafed forms have been found. Notes in the Kew Herbarium state that the plant has been cultivated by the local inhabitants for its seeds in both Kenya and Uganda.

BENGAL COFFEE

Coffea bengalensis Roxb.

There are four Asiatic species of coffee, and it would be just as correct to label them 'Travancore Coffee' as it is to call them Bengal Coffee, for they are all closely allied. Following the system adopted in this book of treating the species in order of their importance to commerce, and at the same time endeavouring to place them in alliance, *C. bengalensis* is entered first because it is said to have a distribution which is more widespread. Moreover, systematic botanists appear to have hesitated to place the species in any real genealogical order, and have disagreed as to which should take precedence. The species are *C. bengalensis* Roxb., *C. travancorensis* Wight et Arn., *C. fragrans* Wall. ex Hook., and *C. wightiana* Wall.

Chenney lists *C. bengalensis* Heyne ex Roem. et Schult., Syst. Veg. 5:200, (1819), as follows. A glabrous shrub with dichotomous sprawling branches. The deciduous leaves are opposite, broadly ovate or elliptic, obtusely acuminate, cuneate; with a very short petiole having persistent awl-shaped stipules. The blades are a dull green, averaging 12 cm. long and 7 cm. broad, and the veins below are pubescent. Flowers are axillary, or solitary, on short twigs, with a pair of leaf-like bracts; they are large, fragrant, and white, being 2·5 to 3·75 cm. in diameter. The corolla tube is 1·25–3·75 cm. long; with lobes which are obovate-oblong. The anthers are linear and sessile, extrorsely attached to the mouth of the tube a little below the apex, only the points being visible. The style is short and the stigma bifid. The fruits are black when ripe and the size of a small cherry, ovoid-oblong in shape, about 1·25 cm. diameter, and didymous when having two seeds. [Syn. *Coffea horsfieldiana* Miq.]. *C. bengalensis* is found in central and south India, in the more tropical parts of the Himalaya, in Bengal, Assam, Siam and Java. It is better known than its allies, and it appears to have been cultivated to a small degree before the advent of Arabian coffee. The beans are small and of inferior value.

Coffea travancorensis Wight et Arn.

The difference in the stipules chiefly distinguishes this species from *C. bengalensis*; they are small, shorter, rounded, and cuspidate. The flowers are smaller and the fruits have deep furrows dividing them into two obvious parts. *C. triflora* Moon., is a synonym.

This jasmine-like coffee is found in south and west India, particularly in Travancore, and also in Ceylon in the warmer moister regions up to an

altitude of about 3,300 feet. It is rather rare, of no commercial importance, and doubt has been expressed regarding its use by the local inhabitants.

Coffea fragrans Wall. ex Hook.

This coffee was once thought to be of economic value, but its product is of poor quality and crops are very light. The plant is seen in gardens because of its beauty and fragrance. A description is to be found in the *Flora of British India*, Vol. 3, p. 154 (1882).

The plant is a glabrous or slightly pubescent bush, which in general is very near to *C. travancorensis*.

Coffea withtiana Wall.

This species is more distinctive and distant from *C. bengalensis*. It is a small bush with rigid and stout branches having a light-coloured bark. The young shoots are pubescent, and the leaves are small, nearly sessile, oval, obtuse and cuneate, no more than 3·75 cm. long and 1·25 cm. broad. The blades are glabrous or somewhat woolly in the axils of the veins beneath, and subcoriaceous. The stipules are spinescent, short, sharply pointed, rigid and persistent, becoming small curved thorns on the laterals. Flowers are solitary, sessile, appearing before the leaves; they are white, 5-merous and sweetly scented. Corolla tube is about 1·25 cm. long, having lobes which are oblong-oval, obtuse, about half the length of the tube, and much narrower than in *C. bengalensis*. The stamens and style are short and included in the tube. The fruit is about 0·83 cm. diameter, broader than long, didymous, with deep furrows between the carpels.

The plant is rather rare. It is found in the hot and drier parts of south-west India from Coorg to Travancore, and also in Ceylon, at altitudes up to 2,800 feet. It was first noted about 1828.

OTHER ECONOMIC ASIAN COFFEES

Coffea jenkinsii Hook. f.

There are two other coffees found in Asia of which mention has been made of their occasional use by the local inhabitants,[1] though this has been questioned.[2]

The first, *C. jenkinsii*, was described in the *Flora of British India*, Vol. 3, p. 155 (1882). It is a glabrous shrub having leaves 7–14 cm. long, and 1·2–4 cm. wide, elliptic-lanceolate to caudate-acuminate, with apex attenuated in a remarkable way to a narrow point 1·5 cm. long. Stipules 0·4 cm. long. Flowers axillary: corolla tubes longer than the lobes, mouth glabrous, lobes 4 in number, acute. Fruit ellipsoid, 1 cm. long, 0·5 cm. broad. The species is said to be near *C. khasiana* Hook., and to resemble in habit the non-economic species *C. salicifolia* Miq., of Java.

The species *C. jenkinsii* was collected by Jenkins and Griffiths about 1880 in the Himalaya region and Khasia mountains at altitudes of 2,800–4,000 feet. *C. braviensis* Drake., is a synonym.[2]

Coffea khasiana Hook. f.

The plant is a sprawling shrub or small tree with grey bark, and the branches and the leaf veins are pubescent. The leaves are rather larger than those of *C. jenkinsii*, but they again have a long whip-like point. The flowers

are yellowish and borne in shortly branched hairy cymes. The corolla tube is 0.4 cm. long, having a villous mouth, and acute, ovate lobes often shorter than the tube. The anthers project beyond the tube but the style is short. The fruit is smooth, rounded, with hairy and persistent calyx teeth. The species is closely allied to *Coffea densiflora* Blume, of Java and Sumatra.

C. khasiana is found in the Himalayas, Mysore, Khasia, and Jyntea mountains, and it was first noted about 1871 growing wild in the Khasia mountains at altitudes between 1,850 and 4,200 feet. (See *Flora of British India.*)

MADAGASCAR COFFEES

Coffea mauritiana Lamarck

Known as Marron, or Bastard coffee, the species grows into a glabrous tree 60–80 ft. tall. The leaves are glossy, lighter in colour below than above, sub-coriaceous, oblong, 9–14 cm. long, 5–7·5 cm. wide, with a short obtuse apex and a cuneate base. The petiole is short and flattened, and the venation of the blade is slender. There are 1–4 sessile 5-merous white flowers in the axils of the leaves. The corolla is 0·60 cm. long, with a short tube. Both anthers and stigma are exserted. The fruit is drupaceous, oblong or obovate, and narrowed at the base. The seeds also are narrowed below. Syn. *Coffea sylvestris* Willd.

The tree is indigenous in the island of Réunion where it is abundant in the forests at 650–4,000 feet, and also in Maurice Island. The plant was discovered in 1715. The seeds are said to have a very low percentage of caffeine,[1] and to give a bitter infusion. It is sometimes called 'bourbon coffee', but it must not be confused with the well-known 'bourbon' strain of Arabian coffee.

A near relative is *C. macrocarpa* A. Rich., [syn. *C. grandifolia* Bojer.] which grows in the dense forests of Maurice Island. In addition, Chevalier lists other species of coffee found wild in the forests of Madagascar. He states that they are incompletely described, and that three, only partially described species, merit further study, because the products of two of them were used by the local inhabitants before the introduction of Arabian coffee. The three are *C. perrieri* Drake (which might be confused with *C. madagascariensis* Drake), *C. utilis* A. Chev., and *C. buxifolia* A. Chev. We must not disregard the possibility of hybridization in these Island regions, for it must be remembered that Arabian coffee was introduced to Réunion and neighbouring islands from 1717 onwards, well over two centuries ago.

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Chapter III

CYTOLOGY, GENETICS AND BREEDING

TAXONOMIC DETERMINATION ESSENTIAL

THE cytological examination of material and the science of genetics must first of all be preceded by a careful taxonomic determination of the species concerned. A genetical exploration may help to clear up doubt within a genus as to whether a species is, in fact, a true one, a mutation, or a chance and natural hybrid. Cytology concerns the contents of the living cell, its manner of division during mitosis, i.e. the self-propagation within the meristem at the growing points, or within the cambium tissues, and the number of chromosomes and their arrangement in the somatic cell. It is also concerned with the phenomena of the meiotic division, when the chromosome number is halved for the production of male and female gametes in the pollen and embryo-sac respectively.

Genetics concerns the genes and their transmissible characters within the chromosomes; how they combine, or may be separated and may interact to form specific or varietal characters. No modern plant breeder proceeds without studying the cytological make-up of his material and the genes he may have at his disposal. Hence he normally searches for, and makes a collection of all the species and variants he can find, so that he may single out the outstanding genes he wishes to use as tools in his breeding programme.

The two fields of cytology and genetics are, therefore, closely allied, and it must be remembered that confusion may quite easily arise among cultivated plants, now that the plant breeder is aided by chemical influences to increase the number of chromosomes within the cell. Chromosomes may be doubled, quadrupled and so on, and the habit and growth of the progeny often becomes quite different; in other words, new man-made species may be evolved, and hybrids may be made to bear viable seeds because the odd number of their chromosomes has been altered so that they may be divisible in equal numbers. Also, a species may be made fit to mate with another species by giving it an equal number of chromosomes in the hope that an interspecific hybrid may result and bear fertile seeds.

It is obvious, therefore, that the old hit-and-miss methods of plant breeding are now obsolete, especially when dealing with a tree-like perennial, the generations of which take so long to grow and display the results of cross-breeding. Plant breeding is now a science, based on cytological and genetical knowledge, though it must be remembered that the old hit-and-miss principle still prevails in natural conditions, which are more risky because of the hazards of life, and the struggle for existence in a hard and difficult environment.

It is in that harsh environment that a species has to survive because of its adaptability. Here circumstances enforce a certain uniformity which may no longer persist to the same degree when the species is taken into cultivation, because mutations or forms may arise in a cultivated field which would promptly be suppressed among wild growths.

It must be remembered, also, that when we are dealing with a crop which can be propagated vegetatively, it is possible to select and use plants which will not grow true to their parents from seed, because their characters are not fixed. Vegetative propagation is hence the only certain means of obtaining a uniform field of a plant which is self-sterile, and which must receive pollen from another tree before it will set seed. This very fact then forces us to plant several clones, as is the case with the diploid species of coffee, before we can obtain economic yields of fruit.

Growers must be properly informed when a cultivated variety cannot be expected to grow exactly true from seed, or when it is necessary to plant a mixture of clones to obtain a satisfactory fertilization of the flowers. A good strain of seed may be developed by constantly mating selected parent trees. Geneticists are sometimes keen on producing pure line selections and scorn a complexity that will not breed true despite outstanding characters which might be of use to commerce. A mixed race, like a mongrel, is often hardier in the field.

In regard to the genus *Coffea* there is still much to learn. Few botanists have travelled extensively where the various species grow wild, and one has only to study the writings of those who have, to appreciate the difficulties which confront them, and the excusable manner in which they may abruptly alter their opinions and reclassify their former work.[1 2 3] All the work hitherto accomplished in the cytological and genetical fields, except in regard to Arabian coffee, perhaps, must therefore be considered in relation to these facts, and the confusion which exists in regard to the genus *Coffea* in the herbaria of the world.

Chromosome counts

In the list of the chromosome counts of the various species of coffee given in the *Chromosome Atlas of Cultivated Plants* by Darlington and Janaki Ammal, published in 1945, the basic number of chromosomes for the genus is shown to be $n=11$. *Coffea arabica* and its forms are given $2n=22$, $2n=44$, 66, and 88. All the other species of *Coffea* listed are shown to have $2n=22$, except *C. abeokutae*, *C. congensis*, and *C. liberica*, which are given $2n=44$ as alternative counts, and these may be based on doubtful determinations. It will be seen that whereas *C. arabica* is polybasic, and usually tetraploid, the other true species of coffee so far examined are proving to be diploids with counts of $2n = 22$ when the determinations are dependable.[5]

EXAMINATION OF *Coffea arabica L.*, ITS FORMS AND VARIETIES

Much of the more recent work on coffee, and in particular in regard to *C. arabica*, has been accomplished at the Institute of Agronomy, Campinas, São Paulo, Brazil, where an intensive breeding programme was started in 1933, under the aegis of the Genetics Division. The author is grateful for permission to quote extensively from the writings of Drs. Krug and Carvalho, and has had the pleasure of meeting the latter in London.

Basic investigations have been carried out, particularly on the genetics of coffee, and a representative collection of varieties and forms of *C. arabica* exists there, including what are termed twenty-five varieties and four forms which have been described at different times by the workers Krug, Carvalho and Mendes. They have considered all new homozygous mutants as new

varieties of a species, whereas the recombination of genes already known, either by accident or intent, has not been accepted as such.

All the species so far examined at the Institute show a regularity which confirms the original conclusions, namely, that *C. arabica* has 2n=44 chromosomes, whereas the remaining species have 2n=22.

The variety of coffee most widely grown in Brazil has been the Arabian variety with the bronze tips to the young twigs and a horizontal branching habit, known in East and Central Africa as var. *nyasa*. In Brazil it has been called 'Nacional' coffee, and more recently *Coffea arabica* var. *typica* Cramer., since the description tallies with that of Linnaeus. If it is the type species, however, it cannot properly be called anything else but *Coffea arabica* var. *arabica*, and for the purpose of correctness it will be referred to as such in this book.

Of the varieties of *C. arabica* arising in cultivation which differ in chromosome count, *C. arabica* 'bullata' has two forms with 66 and 88 chromosomes respectively, and *C. arabica* 'monosperma' is a diploid with only 22. All these are practically sterile on account of abnormal meiosis, so the commercial and better-known varieties all have 2n=44 chromosomes. A feature of 'monosperma' is that the fruits that set are always one-seeded, though the plants flower profusely.[4]

Morphologically the chromosomes of *C. arabica* have been studied by both A. J. T. Mendes and Medina, who found that they do not stain easily at the stage of early prophase. The centromere may be detected between two heteropycnotic regions, but the ends of the prophase chromosomes cannot be seen for they are lost in the cytoplasm. In average cases, 9.2 bivalents occur with only one chiasma, 10.8 with two chiasmata, and 2.0 with three.

The initiation of the seed has been studied by several workers. In the beginning von Faber published an account in which he stated that the bulk matter of a coffee seed was normal endosperm. Houk thought it was perisperm, but several since have disagreed with him, including Krug and Carvalho in 1939. A. J. Mendes confirmed the presence of true endosperm in 1941.[5]

By the use of interspecific crossing, triploids have been obtained which were sterile because of meiotic irregularities. Mendes developed a technique whereby scions were treated with colchicine before grafting, so that chromosome doubling took place. He obtained one hexaploid by doubling the chromosomes of an interspecific hybrid between *C. arabica* and *C. canephora*, which gave him a heterogeneous progeny, and every indication that *C. arabica* was, in fact, an allopolyploid. Doubling the chromosomes in the cv. 'monosperma' (2n=22) resulted in pure lines of tetraploid plants.

Until 1928, many thought that Arabian coffee was pollinated by insects and wind. Using the cv. 'purpurascens' as a genetic indicator, Taschdjian obtained 39 and 93 per cent hybrid seedlings in his seed beds due to natural cross-pollination. He concluded that Arabian coffee was almost allogamous despite its self-fertility exhibited when flowers were bagged.

Using the yellow endosperm mutant cv. 'cera' of Arabian coffee as a genetic indicator, and a more intensive investigation in 1949, Krug and Carvalho found the percentage of hybrid seeds resulting from natural crossing to be only 7 to 9 per cent, thus the flowers of Arabian coffee must be considered almost entirely self-fertile, i.e., predominantly autogamous. The discrepancy in the figures of the different workers is explained by the greater ease and pre-

cision with which the hybrid green seed could be distinguished from those with yellow endosperm.

As for the genus as a whole, all the diploid species have been found to depend on cross-pollination, chiefly by wind and insects, it having been found that the pollen floats in the air and travels for considerable distances.[5] The flowers are usually self-sterile, and on account of this, a genetical analysis of the diploid species is very difficult.

THE GENETICS OF *Coffea arabica* L.

By 1950 some thirty mutants of *C. arabica* had been analysed, and the majority had apparently appeared because of one or more genetic factors.

Of all the mutations, those which depend on a difference in chromosome number are the most striking. A. J. T. Mendes states that the occasional occurrence of unreduced gamets has been supposed to be responsible for the origin of the cv. 'bullata' forms, and the rare parthenogenetic development of a normally reduced egg-cell appears to account for the production of the diploid cv. 'monosperma' plants. Krug and Carvalho state that the observable difference between the octoploid and hexaploid 'bullata' forms is chiefly in the leaf characters, the octoploid having leaves that are more coriaceous and smaller, while both have thicker and broader leaves than normal tetraploid forms of *C. arabica.* The diploid cv. 'monosperma' in addition to the one-seeded fruits, has narrow and thin leaves obviously differing from those of the tetraploids, and, in so far as stomata counts are concerned, R. M. Franco stated in 1939 that an inverse relationship exists between the number of chromosomes and the number of stomata per unit area of the leaves of these forms of *C. arabica.*

Instances of chromosomal mutation have been observed in Brazil. Tetraploid plants have grown branches that were octoploid, and the reverse, while diploid stock has mutated tetraploid material. According to Krug, no diploids have arisen as mutations from tetraploid plants. None of these chimeratic forms differing from the 2n=44 count in *C. arabica,* has any commercial value, since their productivity is low. All of the few seeds which were found to be viable gave normal plants with 2n=44 chromosomes.

To establish the dominant relationships of the genetic mutants of Arabian coffee, all were crossed in Brazil with the var. *arabica* (known there as *typica*) or var. *bourbon,* selected because the first was regarded as the primitive type and the second closely related. By crossing var. *arabica* with 'murta' and 'nana' mutants, information has been obtained concerning the genetic make-up of var. *arabica.*[5]

When 'nana' is crossed with var. *arabica,* the F 1. are nearly normal, and these when selfed present a series of plants which can be classified as var. *arabica,* var. *bourbon,* 'nana', 'murta', and a new form of 'murta' with larger leaves. It was assumed that if var. *arabica* carried another dominant gene AA in addition to the NaNa genes, and if the nana plants were double recessive for these 'a' genes (nana aa), then it should be possible to get by selfing the F 1. (Aa Nana) plants, the following in F 2.:

AA NaNa	...	var. *arabica*
AA Nana	...	almost var. *arabica*
AA nana	...	almost var. *bourbon*

Aa NaNa	...	var. *arabica*
Aa Nana	...	almost var. *arabica*
Aa nana	...	'murta' with large leaves
aa NaNa	...	var. *bourbon*
aa NaNa	...	var. *bourbon*
aa Nana	...	'murta'
aa nana	...	'nana'

It seems that the 'A' gene is epistatic over na, and Na becomes dominant over na in the presence of aa, resulting in two forms of the 'murta' mutant. If the 'murta' plants with the large leaves (Aa nana) are selfed, then the progeny include normal AA nana plants with even larger leaves, as well as the 'murta' individuals with large leaves (Aa nana) and the dwarf plants (aa nana), in the proportion of approximately 1 : 2 : 1.

Krug and Carvalho argue that on the basis of these results it is evident that there is a genetic difference between the var. *arabica* and the var. *bourbon*, the *bourbon* being double recessive (aa) and the *arabica* carrying the dominant alleles of the 'A' gene. They state that all the forms and so-called varieties of *Coffea arabica* can now be grouped into the classes having either aa or AA characters, which they note by using the letters tt and TT for *typica*.

Since this aids a decision as to whether a mutant has been derived from one or the other, it has been possible to state that the mutants 'caturra', 'semperflorens', 'laurina', and others have sprung from *C. arabica* var. *bourbon* whereas the 'maragogipe', 'cera', 'goiba', 'calycanthema' and other mutants originated from *C. arabica* var. *arabica*.

The mutants have all arisen or been noted in cultivated fields, and even the Mocha or Mokha Arabian coffee may be presumed as having originated under cultivation in the Yemen region of Southern Arabia. The author prefers, therefore, to list them according to the new International Code as cultivars. The genetic findings recorded above tend to uphold this decision to award only two botanical varieties to *C. arabica* L. namely var. *arabica* and var. *bourbon* and call all the other forms of Arabian coffee cultivars.

The authors of the research at Campinas state that if, as they believe, the var. *arabica* referred to by them as typica is the primitive type, then the mutation from 'A' to 'a' must be considered of real economic importance. The var. *bourbon* was obtained in this manner and it is reputed to give higher yields than var. *arabica*. The genetic tester used to decide this question was the common 'murta' mutant (aa Nana).

Mutants of academic interest

A mutant known as var. *angustifolia* (Roxb.) Miq., which may now be called cv. 'angustifolia' has various genetic factors which are responsible for the phenotype, according to Krug and Carvalho. The shape of the leaves is the main characteristic, for they are elongated and narrow, being thicker than var. *arabica* with less prominent veins and generally without domatia.

The authors list two recessive independent genes ag 1-ag 1, and ag 2-ag 2, which give rise to the phenotype, both having pleiotropic effect and influencing the size and shape of the plant. The ag-1 factor causes the abnormal development of a shrubby growth with numerous stems growing from the base, the branches being slender and brittle and the yield very low, while the ag-2 has a similar effect but the plants then grow only one main stem. By crossing these two a normal F 1. develops, and in the F 2. generation a ratio of

9 normal to 7 'angustifolia' plants is found. Some other 'angustifolia' plants differ, however, in their genetical behaviour.

A mutant named 'anomala' was discovered in 1933 in a very old plantation at Campinas, and is extremely rare. The size of the shrub was abnormally large and nearly all the vegetative parts including the reproductive organs were abnormal. A rare mutant named 'anormalis' is also extremely variable in all its parts, as for instance the internodes, which are sometimes long and sometimes short.

A plant bearing flowers with large sepals to each calyx was found in a plantation in 1935. It produced very few fruits and seeds and is said to be female-sterile. The mutant is again rare and was named 'calycanthema'.

The mutant 'goiaba' is stated to have a well-developed and persistent calyx of five sepals, so that the fruits have the appearance of small guava fruits or gooseberries. It was found on a private farm close to Limeira in the State of São Paulo. When a normal plant is crossed with 'goiaba' the F1. have calyces of intermediate size, the F2. segregating into SdSd normal, Sdsd intermediate, and sdsd with well-developed sepals in the ratio of 1 : 2 : 1.

If homozygous 'goiaba' plants (sdsd) are crossed with plants heterozygous for the 'calycanthema' gene (Cc), then 50 per cent 'calycanthema' (Sdsd Cc) and 50 per cent heterozygous 'goiaba' plants (Sdsd cc) have been produced. The 'C' gene is, therefore, completely epistatic over sd, for plants of the constitution sdsd Cc are of the 'calycanthema' form.[5]

Plants which flower several times in succession and often at times of the year when neighbouring plants are not in flower have been found in Brazil among *C. arabica* var. *bourbon*. The mutant has been named 'semperflorens' and it frequently has buds, open flowers, and fruits of different sizes on the branches at the same time, which reminds the author of how often the Arabian coffee behaved like this in the warmer unsuited regions of Uganda. Although ripe coffee may be picked from this mutant at almost any time, the peak periods of its yield in Brazil are two, one at the normal time and the other in November or October. All the surrounding coffee in the field will have only one harvesting period.

At Campinas they say that these characters are controlled by one pair of recessive factors (sfsf). These genes also give a more upright growth to the branches. After a cross between 'semperflorens' and normal plants the F1. generation is entirely normal, the F2. segregating into 3 normal and 1 'semperflorens'.

A mutant with very small crinkly leaves has been given the name 'crespa'. Crosses between 'crespa' plants and normal plants of var. *arabica* gave seedlings which segregated into 50 per cent 'crespa'. This indicates that the crinkly-leaved plants were heterozygous for one pair of characters (Crcr). By selfing, both normal and 'crespa' forms were obtained. Some of the 'crespa' plants were small and of slow growth and they were presumed to be homozygous (CrCr). The gene has a noticeable pleiotropic effect on the branches which are more slender than normal plants. The flowers are few and the set of fruits tinged red in colour is poor.

Cramer described a mutant of Arabian coffee in Java which he called 'erecta', that develops erect-growing laterals. Whereas most forms of Arabian coffee have normal plagiotropic branches which spring from the main stem at an angle of 65 degrees, the branches of 'erecta' are at an angle of about 25 degrees.

According to Krug and Carvalho,[5] a genetical analysis showed that one pair of genes (ErEr) was dominant and responsible for this striking branching habit. The F1. progeny from a cross between normal and 'erecta' plants were no different to the homozygous 'erecta' plants, an obvious segregation of 3 'erecta' to 1 normal appearing in the F2. generation. The gene is said to exhibit complete penetrance and constant expression.

Despite the erect growth habit of the laterals, it is still impossible to graft a lateral on to a main stem and obtain a vertical growth. Plants grafted with laterals of 'erecta' make low-growing shrubs.

There are two forms of fasciation in Arabian coffee, one of which is not hereditary and may occasionally be seen in plantations. The form of fasciation which is genetically controlled is named 'fasciata' at Campinas, for it represents the main character of the cv. 'polysperma' described by Cramer in detail in 1913.

The seeds of Arabian coffee are normally greenish when dry, though the colour fades out as the seeds get older if they are kept in storage for a long while. The endosperm of some other species of coffee is, however, yellow, and in 1935 several Arabian coffee trees in private plantations in São Paulo State were found to produce seeds with yellow endosperm. These mutants were given the name 'cera'. All the other characters of these plants resembled the var. *arabica*.

By crossing 'cera' with normal male plants, green hybrid seeds were produced, which, according to Krug and Carvalho indicates that the 'cera' alleles (cece) are recessive to one dose of the normal allele Ce. A closer genetical analysis is said to have shown that the endosperms of genetically constituted plants such as Cecece, CeCece, and CeCeCe are all equally green.

The first genetical investigation made at the Institute of Agronomy, Campinas, São Paulo, concerned the 'murta' mutant which is related to var. *bourbon* Arabian coffee. When progeny of 'murta' plants were selfed, 3 genotypes were obtained; bourbon, nana and murta in the proportion 1 : 2 : 1. Only one pair of factors was involved in this segregation, the 'nana' plants varying in size with some tending to resemble the 'murta' form. 'Murta' plants have smaller leaves than var. *bourbon*, and 'nana' plants are extremely slow in growth, some of them not flowering at all, whereas others may flower after a period of 8 or 9 years. Carvalho found that the 'nana' gene was unstable in the somatic tissue, often mutating to the dominant condition.

Plants with a red or a purplish colouring were given the name 'purpurascens' by Cramer. The young leaves are dark purple while the older leaves retain the colour to a lesser degree. The flowers are pink, and the young green fruits may show purple sections along with green. The mature fruits resemble the var. *arabica* but the yield is poor.

When crossed with green-leaved plants (brbr), the 'purpurascens' becomes recessive, the F 1. having green leaves. When crossed with plants having marked bronze colouring of the young leaves (BrBr) the F1. produces young leaves of a darker bronze. In F2. three phenotypes occur, and these may be described as (*a*) plants with purple leaf colour, (*b*) plants with young green leaves, and (*c*) others which vary in the depth of the bronze leaf colour. Krug and Carvalho conclude that a primary pair of genes (prpr) is concerned with the purple coloration, the prpr gene being hypostatic in relation to the brbr, though its mode of interaction with the Br had not been definitely established.

A number of other mutations have been seen to occur, and this is not surprising in view of the high chromosome count in Arabian coffee. There is one with dark green and shining leaves, forms in which the branching is pendulous, plants bearing fruits having larger disks, other forms of abnormal branching, some with mucronate leaves, the San Ramon cultivar, laurina forms with seeds pointed at the distal ends, and plants having leaves in threes, trifid stigmas, carpels in threes and hence three-seeded fruits.

Bronze tipping

The genetical research into the bronze colouring of *Coffea arabica* is interesting. *C. arabica* var. *arabica* has the bronze colour factor in its young leaves but the var. *bourbon* does not. Where bronze tipping is present the very young leaves are green but they take on the bronze colour under the influence of light, the duration and depth of colour depending on the intensity of the light. As the leaves grow older the bronze colour begins to fade and the adult leaf becomes green.

Krug and Carvalho say that only one pair of genes controls this development.[5] The young leaves of plants having the Br genes develop a dark bronze tipping, the double recessive individuals having light green leaves. Heterozygous plants (BrBr) have only a light bronzing.

The dark bronze is, therefore, not quite dominant over the green. The authors report a variation in the degree of the maximum intensity of the bronze colour among homozygous plants of different parents. They suggest that modifying factors are responsible for this, or various alleles occur at the same locus.

Mutants of commercial interest

Though the well-known cultivar 'maragogipe' is a gigantic form of *Coffea arabica* it still has the same number of chromosomes, i.e., $2n=44$. Most of the plants are, however, heterozygous. In comparison with var. *arabica* or var. *bourbon* the yield is disappointing, but the bean is of a large bold size and the quality is good. A fair amount of success has attended the efforts at Campinas to select more productive forms, and on account of its vigour the plant is useful as a parent in varietal hybridization.

'Laurina' coffee forms a small conical-shaped bush with smaller leaves than the type species, and the fruits and seeds are somewhat pointed at their bases. In Brazil the plant has given steady yields of good quality coffee even under droughty conditions. It was formerly named *C. arabica* L. var. *laurina* (Smeathman) DC.

Mocha, Mokha or Moka coffee is thought to have originated in Arabia in cultivated fields. The true mutant is found as a small conical shrub with quite small leaves bearing relatively large domatia. The flowers are small and the fruits and seeds are smaller than any other known form of Arabian coffee. The yield is poorer than the larger-seeded forms but the quality is said to be excellent.

Doubtless the Arabs of the Yemen favoured this variety for some special reason, maybe because it was drought resistant or adapted to their mountainous regions, and for such reasons a great deal of the coffee which was once exported from Mocha was of this kind. 'Mocha' coffee now finds its way to Aden by dhow via the small port of Hodeida, or by camel-back across the frontier where it is bought by the coffee merchants of Aden.

Streaming into Aden from other sources comes half-empty 'buni' cherry coffee from East Africa, and coffees from Somaliland and Ethiopia. The buni coffee is hulled and the small percentage of beans found are of small size and therefore useful for blending purposes. Indeed, much of the 'mocha' coffee exported from Aden is a mixture of Arabian coffee from many sources, of which only a proportion may be true 'mocha' coffee.

Following considerable study of the F2. and F3. generations at Campinas, it was ultimately decided that the characters of the 'mocha' coffee plants are controlled by two pairs of genetic factors, one of which (laurina lr) is recessive and the other (mocha mo) has a dominance which is not entirely complete.[5] True 'mocha' plants lrlr-momo are closely related to the 'laurina' mutant lrlr-MoMo. By crossing the 'mocha' mutant with var. *arabica* or var. *bourbon* the genotypes found in the F1. and F2. generations are as follows:

P 1.	LrLr MoMo × lrlr momo.		
F 1.	Lrlr Momo.		
F 2.	LrLr MoMo	...	normal.
	LrLr Momo	...	similar to F 1.
	LrLr momo	...	similar to 'mocha' when adult.
	Lrlr MoMo	...	normal.
	Lrlr Momo	...	similar to F 1.
	Lrlr momo	...	similar to 'mocha' when adult.
	lrlr MoMo	...	'laurina'.
	lrlr Momo	...	'laurina' with round seeds.
	lrlr momo	...	'mocha'.

The leaves of the F1. plants are a little smaller in size with the domatia slightly more protuberant than var. *arabica.* F2. plants of LrLr momo and Lrlr momo exhibit abnormal branching in the seedling stage, for the laterals only develop at the 25th or even the 36th pair of leaves, so that the main stems have no low laterals. On normal plants the laterals begin to grow from the 9th to the 11th leaf axils on the main stem. The leaves are a little larger than those of the 'mocha' mutant with the domatia developing to a very noticeable degree. New upright stems appear after planting with the laterals at a normal height, so that the adult plants appear similar to true 'mocha' though a little larger in size. The genotype lrlr Momo resembles 'laurina' lrlr MoMo. It is thus possible to produce a form resembling 'laurina' by crossing 'mocha' with var. *arabica* or var. *bourbon.*

In 1871 a yellow-fruited variety was discovered as a mutation in a field of coffee in Butucatú country in the State of São Paulo, Brazil. It was named *Coffea arabica* L. var. *amarella* Hort. ex Froehner, and as 'amarella' coffee it has been subsequently known, though some have referred to it as 'Butucatú' coffee or as 'Golden Drop' coffee. Krug calls it var. *xanthocarpa*, but it is a cultivar, and first and common usage makes it advisable, perhaps, to call it cv. 'amarella'.

'Amarella' coffee was soon propagated and grown in many regions of São Paulo State. It apparently resembles the var. *arabica* in every way except in the colour of its ripe fruit. The yellow colour is controlled by one pair of genes which Krug has listed as xcxc. The red colour XcXc is almost dominant over the yellow, the F1. producing red fruits of a paler red. The yellow fruits occasionally exhibit sections which are red in colour due to somatic disturbances, and similar streaks of dark red appear on fruits of hybrid plants. By

crossing 'amarella' with 'purpurascens', yellow fruits are obtained in the F2. in the purpurascens mutant. The yellow colouring is then of a darker shade.

It is said that the 'amarella' mutant brings about increased yields, and this has been found true in a yellow-fruited form of var. *bourbon*, and a yellow-fruited form of cv. 'caturra'. The true cv. 'amarella' is a yellow-fruited form of var. *arabica* according to Krug, so when the genes causing the yellow colouring are transferred to var. *bourbon*, and a yellow form of bourbon coffee is obtained, or when they are transferred to cv. 'caturra' which has itself sprung from var. *bourbon*, then, to avoid confusion, new names should be coined for these new yellow-fruited forms. They have been referred to as 'forma xanthocarpa' in each case, and for genetical purposes this might suffice. If, however, they are issued for commercial planting as newly-bred forms having a considerable difference in their genetical make-up, then they should be given separate cultivar names.

Swamy reported that the bronzing of the leaves and the yellow colouring of the fruits appeared to be linked, but Krug and Carvalho do not agree for they assert that the controlling genes are separately inherited. No case of linkage has so far been proved.

The mutant known as 'caturra' is thought to have originated in the State of Minas Geraes, Brazil. It closely resembles var. *bourbon* except that the internodes are shorter, the leaves a little broader and the plant a little smaller in size. It is, however, very productive and for this reason it has importance. It has been extensively cultivated of recent years in the State of São Paulo and other coffee-growing regions of Brazil.

When normal plants are crossed with the cv. 'caturra' 100 per cent plants similar to 'caturra' appear in the first generation. A back cross to normal plants segregated 50 per cent normal and 50 per cent 'caturra', and a back cross to 'caturra' gave 100 per cent 'caturra'. Since only the size of the plant and differences such as the length of the internodes were concerned, it was not possible to separate homozygous and heterozygous individuals among young seedlings.

The data obtained showed that the 'caturra' characters were controlled by a pair of genes which exhibited complete dominance. Krug and Carvalho gave the symbol CrCr to the pair of genes concerned.

Perhaps the most important cultivar among Arabian coffee field varieties is the cv. 'Kent's', which originally appeared in a plantation in India. It has a wonderful stamina, the branching habit of var. *bourbon*, and yet gives evidence at times of bronze tipping applicable to var. *arabica*. Its main attributes are rust resistance and high yield of excellent quality coffee. The author has often observed its resistance to pests as well, for supply plants among bourbon coffee infested with green scale remained clean.

Though Indian technicians have crossed many Arabian coffee selections with 'Kent's' coffee to transfer its stamina and resistance to disease, no one has published data concerning its complete genetical make-up. This is surprising, because, on account of the absence of rust disease in Central and South America, and the fear of its appearance at some future date, it would seem most advisable to introduce and breed this resistancy into Arabian coffees grown in the Western Hemisphere. The acquisition of 'Kent's' coffee has altered the chances of growing Arabian coffee economically in African and Eastern countries where the leaf rust disease is prevalent.

Flower opening

The flower buds generally open on sunny days in the early morning, and pollen shedding starts soon afterwards. The stigma is immediately receptive. The pollen is not sticky and it is produced in relatively small quantity. It is carried by the wind, and by insects, and may fall by gravity on to the flowers of the lower branches. On cloudy days the buds tend to remain closed even though they are fully developed, and when they fail to open through lack of sunshine, the maturation process goes on normally in the anther-sacs independent of external influences. The pollen is, therefore, often shed within the flower bud. About two days after opening or fertilization within the bud, the flowers begin to wither, and a few days later all the flower parts drop away except the ovaries. If pollination does not take place the style and stigmas may remain turgid for much longer.[4]

Technique of crossing at Campinas

Flower buds are rapidly and easily emasculated by using a pair of scissors especially adapted for the work. A small nick is made in each blade of the scissors and a piece of metal is attached to one handle in such a way that the blades cannot be entirely closed. The scissors are applied with the notches in the blades approximately at the middle of the corolla-tube, and by closing the scissors only the corolla-tube is cut, the style being untouched. With a slight upward movement the whole corolla is pulled away together with the stamens, without touching the delicate pistil at all.

After the desired flowers on a branch have been emasculated, and all the other berries and flower buds on the branch have been carefully removed, the branch is covered with a paper or cloth bag. The branch should be labelled with a conspicuous label so that it can easily be seen after the bag has been removed. At the same time a few branches of the male parent with flower buds of about the same size are also covered with bags. Two or three days afterwards the stigmas of the emasculated flowers are examined, by which time the lobes are generally well expanded and receptive. The open flowers from the protected branches of the male parent are then collected by means of a pair of sterilized forceps and carried to the female parent in small closed glass containers. After pollination the bags are retained on the branches of the female parent for about a week.

Genetical Study of Other Species

It must be remembered that Arabian coffee is self-fertile and cross-fertile, whereas the other species are usually self-sterile so that they need pollen from other plants of the same genus of a slightly different genetical constitution to produce viable seed in economic quantity. It is often difficult to find viable seeds which will produce useful plants when fruit is obtained by selfing.

The genetical study of the diploid species is not easy on this account, and very little work has been attempted to date. Since cross pollination by wind and other agencies is the rule, it is not surprising to find a great deal of variation in all respects in each of the specific groups, so that forms may be found that appear to resemble some neighbours in another group. This makes it difficult to draw a line and distinguish some forms of *C. canephora* from others of *C. liberica*, or of the latter from *C. excelsa*.

Due to the taxonomic confusion which still exists, there have been a lot of references to interspecific hybridization which may not be interspecific at all. Some of these hybrids have been said to be successful, such as the 'Conuga' or 'Congusta' hybrid obtained as a natural and very haphazard cross between *C. ugandae* and *C. congensis* in Java. It is being acknowledged, however, that there is every likelihood that these parents are not separate species, and are, in fact, both forms of *C. canephora* which might be expected to hybridize easily, the *congensis* possibly being an ecotype adapted to a light moist soil, and a dwarf form of *canephora*.

Self-sterility being the rule, it is astonishing that distinctive forms may be found to persist among, for instance, *canephora*, so that dominance of character would appear present in the sturdy tree-like form var. *canephora*, and the rounded bush-like form var. *nganda*. The author would like to theorize and suggest the possibility that, just as we have the two opposites in Arabian coffee, i.e., var. *arabica* and var. *bourbon*, so may we have them in other species of coffee, with all the possible mutants surrounding them partly hidden by self-sterility and the constant cross fertilization that takes place between the forms.

It is stated that a greater number of mutants are known in the tetraploid *C. arabica* than in the diploid species, but this may be refuted as knowledge accumulates and the many forms hitherto named as separate species become recognized merely as forms or mutants of two or three diploid species.

In so far as cytological data are concerned one hesitates to mention very much, since it may be based on wrongful determinations. *C. dewevrei* which A. J. T. Mendes speaks of as *excelsa* coffee may ultimately be found closely allied to, if not a form of *liberica*. He found that the somatic chromosomes could be divided into three classes according to size, which varied between 1.0 and 3.3 microns. Three of the main chromosomes could easily be distinguished, he said, one having a secondary constriction.

Prophase chromosomes of *C. canephora* were studied by Mendes and recorded in 1950, their morphology being difficult to observe at pachytene stage. The centromeres were visible in all the chromosomes, heteropycnotic areas being visible on each side of them. The ends of the chromosomes were not easily recognized in this phase and one or two of them were attached to the nucleolus. At metaphase I, on the average 8·4 bivalents occurred with only one chiasma, 1·6 with two chiasmata and 0·97 with three chiasmata.

INTERSPECIFIC HYBRIDS

A number of hybrid plants have been obtained following crosses between different forms and mutants of *C. arabica* and *C. canephora*, $2n = 44 \times 2n = 22$. All have been triploids with $2n=33$. When compared with their parents the hybrids are generally intermediate in regard to most of their morphological characters. Growth is often slow in the beginning but becomes more normal as the trees mature. True interspecific hybrids using *C. arabica* as one of the parents, have been highly unproductive in Java on account of their triploid nature, and though the hybrids may flower abundantly, and the flowers appear normal, very few fruits are produced. Krug and Mendes have recorded that the pollen grains are extremely variable in size on account of the number of microspores formed. In *C. arabica* × *C. canephora* ($2n = 33$) the diameter of the pollen grains varied from 8–48 microns. Germination

tests indicated that they were almost sterile, whereas the pollen grains of normal tetraploid *C. arabica* (2n=44) gave a percentage of over 90 when germinated under identical conditions.

Selfed plants produced only very few mis-shapen fruits containing a few irregular seeds with abnormal embryos of which none germinated. No seeds were obtained when flowers of normal *arabica* or *canephora* were pollinated with hybrid pollen.

Hybrids *C. canephora* × *C. arabica* cv. 'mocha' have leaves intermediate in size with larger domatia, showing that the 'mocha' genes (momo) exert incomplete dominance. *C. canephora* × *C. arabica* cv. 'polysperma' (FsFs) produces a hybrid with a degree of fasciation, indicating that the Fs gene has incomplete dominance in the interspecific make-up. In one tetraploid hybrid which may have originated because of the combination of two genomes of *canephora* with one of *arabica*, the fasciation was less evident, possibly because two 'normal' alleles of the fasciata gene of *canephora* reduced the expression of one dose of the fasciation gene of *arabica*.[5]

Hybrids obtained by crossing green-seeded var. *bourbon* (female) with yellow-seeded *excelsa* (*dewevrei*) as the male parent, gave plants with yellow endosperm, which indicates that one *excelsa* gene for the yellow seed colour was dominant over two doses of the green endosperm of the Arabian species. The leaves of the hybrid more closely resembled the *excelsa* species than the Arabian.

According to Ferwerda, spontaneous interspecific hybrids between *C. liberica* and *C. arabica* arose in Java which were self-compatible.

Whereas varietal hybridization guided by increasing knowledge of the genetical make-up of the parents used, promises results which may benefit the commercial production of Arabian coffee, there would be very little hope of any economic gain from interspecific hybridization were it not for our new knowledge of how to vary the chromosome count by chemical means. Treatment with colchicine can now double the chromosome counts of the diploid species from 2n=22 to 2n=44, and make them equal to the number found in the commercial varieties of *C. arabica*. It is then possible to make an interspecific cross so that the progeny is no longer a triploid but a tetraploid with 2n=44. We must look to the future to see what surprises there may be in store.

A tetraploid hybrid is said to exist at Campinas, the result of an accidental cross between *C. arabica* and *C. dewevrei*, the latter having contributed in all probability two sets of chromosomes. The plant has extraordinary vigour and productivity, and it has been used extensively in a backcrossing programme in an attempt to isolate new vigorous strains with better cup qualities. In general all recessive mutants of *arabica* behaved as recessives in the interspecific hybrids, and all dominant genes of *arabica* have maintained their dominant expression when crossed with this new tetraploid form.[5, 6]

The diploid species themselves, i.e., *C. canephora*, *C. liberica*, and *C. excelsa* (2n=22) can all be crossed with each other with greater ease, and several productive hybrids have been obtained, though there is little reason to carry out this work since none has the cup qualities of Arabian coffee, and selection work among *C. canephora* has already given excellent results.

Genetical Examination of Diploid Species

A limited amount of information is now available at Campinas regarding some mutants of *C. canephora.* For instance, fasciation in *canephora* is brought about by one pair of recessive genes fs/c fs/c, whereas in *arabica,* fasciation is of incomplete dominance. It cannot be said as yet that the same gene occurs in both species. When two plants of *canephora* are crossed which are heterozygous for fasciation, the resulting progeny segregates in the proportion of 3 normal to 1 fasciate. As in *arabica,* the gene affects the fasciation of the stem, the branches and the flower parts.

In *canephora* another mutant occurs. Dwarf plants are seen which grow very slowly and produce only a few fruits when they flower. By crossing two hybrid plants for this dwarf factor, progeny are obtained which again segregate into 3 normal and 1 dwarf. The symbol na/c na/c has been proposed for this gene. The two genes fs/c and na/c must be independent since an approximate segregation of 9 : 3 : 3 : 1 is obtained by crossing two plants heterozygous for both factors. Mutants with narrow leaves and yellow endosperm in the seeds have also been discovered in the *C. canephora* species.

As for *C. excelsa,* Chevalier reported forms with pink flowers; also others with green stigmas and others with corollas which persisted after they had shrivelled.

Cytoplasmic Inheritance

Cytoplasmic inheritance is said to occur to a certain extent in Arabian coffee plants with variegated leaves, where abnormal plastids are present in one or more layers of the leaf tissue. When these are found in only one of the cell layers, areas of pale green are observed, whereas, if they are present in two or more layers, yellow and perhaps white areas are formed.

Variegated coffee plants when selfed give rise to green and variegated progeny in variable proportions. When selfed seeds produced in the axils of green leaves are sown alongside selfed seeds produced in the axils of variegated leaves of the same branch, the former produces only green-leaved plants, and the latter variegated ones. Moreover, green branches grafted on variegated stock remain green.

The variegation is not transmitted through the pollen, as hybrids obtained by using variegated plants as the male parents, have green leaves, though variegated progeny do occur to a small extent in reciprocal crosses. The selfed progeny of the first cross do not produce variegated leaves, showing that there is no genetic factor determining the appearance of abnormal plastids.

The Selection of Outstanding Mother Plants or Varieties

A variety which may do well and serve commercial interests best in one country may not necessarily be the best to use in another, because of the influences of environment. The same holds good for any one country where the separate coffee-growing regions differ widely in any one part of their environment, as for instance in the type of soil, the temperatures, humidity and rainfall. In other words a variety or a strain of seed must be adapted to or suited to a region.

Where this has already taken place, strains of coffee which have become

renowned for their quality in certain countries have been given names which have almost attained the status of a variety, at least in commercial circles. Hence we get 'Blue Mountain Jamaica', 'Kenya coffee' or 'Kilimanjaro coffee', the latter a mixture of var. *bourbon*, 'Kent's', and several other introduced kinds such as 'Menado', and including local selections, mutants and so forth all mixed together and grown on adjacent estates so that a certain amount of varietal hybridization is taking place all the while, building up a heterogeneous strain.

According to Schweizer,[4] Ottolander brought together as many varieties or strains as he could find which had been selected in Java over a period of 200 years. These included Malang, Menado, Padang, Preanger and Tjikenmeah, but when they were planted side by side on the Idgen plateau he could find no difference in these strains although they could be morphologically distinguished in their original locality. The Blue Mountain Jamaica has been found to be suited to some parts of East Africa but not to others, and var. *bourbon* appears to vary a good deal in its suitability to different environments, when this variety is spoken of as a strain.

In any of the older coffee-growing regions, planters have generally taken seed from old proved trees, so that there has been unconscious selection of a strain adapted to the locality because of the gaps which are found in old plantations. These gaps, one might presume, have been occasioned over a period of years by the dying out of trees less suited to the environment. In fact, when one is selecting for health and high yield one is automatically selecting for adaptability to the local environment. The resultant strain might not do so well elsewhere.

It would be wise to try out as many of the known varieties and forms as possible in a new area, a task most suited to a central trial or experiment station which would be concerned with avoiding the introduction of pests and diseases. When once the best strain had been decided upon and planted, then local selection could start to find the best individual mother trees. Since *Coffea arabica* is predominantly self-fertilized, it is not necessary to isolate multiplication plots by planting them very far apart.

The relation between the yielding capacity of selected mother trees and their progeny is not easy to determine, and definite information can only be obtained by field trials over a longish period of years, which would include both the clones and the progeny derived from the original selections. In general, however, comparisons of data have shown that outstanding mother plants tend also to produce outstanding progeny.

A great deal of this selection work has been done at research stations in Kenya, Tanganyika and India, and also in Central American countries and Brazil. As a result of all this work, high-yielding progeny and strains of seed have been built up and given numbers to distinguish them one from the other, rather than varietal names. They might be looked upon as ecotypes suited to each particular locality until they have been proved to give equally good results in other regions. In India, for instance, there is the S.288 Arabian strain, which, apart from its resistance to leaf disease and increased yield is reputed to be resistant to eelworms. There is also the S.274 strain of *C. canephora* (robusta coffee) which has consistently given high yields of bold bean. Both these strains are much sought after by local planters.

Obviously throughout the world the various mutants will occur again from time to time and be selected and given names which are synonymous. Many

names will not occur in this book, partly for this reason, partly because they were once considered important but are no longer considered of interest to commerce, partly because they were never important enough or distinctive enough to become widely known, and also because of the author's ignorance of their existence.

More about the selection of seed strains from mother plants will be found in the chapter on propagation. Data have shown that if records of the fourteenth or fifteenth annual production are taken, or even of only one of these later high-yielding years, the chance of selecting good Arabian mother trees is almost the same as if selection were based on records of all the consecutive years until the trees were fourteen or fifteen years old. This knowledge is of great practical importance, for in adult plantations it is sufficient to base a rough selection of mother trees on only one or two years of recorded yields. If biennial bearing is common, selection must be made during the years of high yield.[6]

To discover how much the yield differences between mother plants are due to environmental factors or genetic influences it is recommended that their progeny should be directly tested in replicated trials instead of waiting and wasting time by first multiplying the mother plants vegetatively and studying the clones. This is good enough for commercial purposes, though it might not suffice for fundamental research in regard to other objectives.

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Chapter IV

ENVIRONMENT AND PHYSIOLOGY

The Meaning of Environment

Many influences are given by environment which of course comprises everything surrounding the object which is being discussed. Firstly, for example, plants are suited to one kind of soil or another—one that is sandy and light, a medium loam, or a heavy clay. Much depends on whether a soil is porous and well-drained, of good structure, with a plentiful organic content and supply of nutrients. The *p*H value is important, for many crops prefer a neutral soil, whereas others grow best when a soil is acid or alkaline.

Next there is the moisture supply, i.e., whether the rainfall is sufficient and well spread or erratic, whether the region is subject to freak storms including hail storms which can be very damaging. The atmosphere may be humid, dry, or variable, and the benefit derived from the rain depends again on the soil. That is, it depends on whether it can absorb and retain moisture or lose it too quickly. Much can be done by moisture conservation practices, but it is too difficult to alter the nature of the soil over large acreages except over a long period of years. Its structure can be maintained, but it takes time to improve a soil in this respect.

Light intensity and duration can be very important and there may be periods when sunshine and dry weather are essential to ripen the wood and initiate flower buds, or to permit a free distribution of dry pollen when the flowers open.

A still atmosphere is not especially desirable, nor are strong winds on exposed hillsides. The ideal is a free movement of air with light breezes. Whereas little can be done to alter the circumstances of a deep and sheltered valley, windbreaks may make an exposed situation suitable for the crop.

Temperatures are of vital importance, and it is best if they do not vary too greatly from one extreme to another within the range desirable for coffee. Temperatures affect the air, soil, and plant itself, and different species of coffee are sensitive in this respect. Arabian coffee, for instance, will flourish at cooler temperatures than those which are best for robusta or Liberian kinds. High temperatures can be mitigated by overhead shade and by mulching. Temperatures and environment will alter very widely at the same altitude depending on the distance from the equator, the lie of the land, the distance from the sea and the direction and origin of the winds.

All these influences comprise the environment, and they must correlate and fit together to form the ideal for each species of coffee. If they do not, then the unfavourable influences must be capable of being altered artificially to simulate the ideal for the species or variety being grown.

This applies when the wild plant is taken out of its natural habitat into cultivation. The wild form may be one which has survived in its indigenous locality. It may have in its genetic make-up other forms which have been suppressed in their natural environment, but which appear as mutants when the species is cultivated elsewhere. Man may select from these mutants those

which have rooting systems which suit a lighter or a heavier soil, or constitutions amenable to warmer temperatures, less moisture and even drought or cold resistance. Lastly there may be forms such as the 'Kent's' Arabian coffee which are found to exhibit a resistance to the pests and diseases of a new environment.

In other words, breeding and selection come into play to create strains of coffee which will grow well enough in situations considered far from the ideal environment. Wherever coffee has been grown over a long period, the strain may have altered imperceptibly by unconscious or natural selection until it suits an environment which may differ from the recognized ideal for the species.

Marginal land that fails to reach the ideal in any one respect, and cannot be altered artificially to agree with a dogmatic ruling as to environment, need not be considered unsuitable if a different strain of seed can be found which will ignore the apparent deviation from the ideal and still thrive.

Though the area concerned may not give the best environment for healthy and first-class growth, it may still be possible to grow a crop and obtain economic returns. In the long run it is the economy of production that matters, albeit we know that greater profits should accrue when the environment is satisfactory.

Indications of Correct Environment

When a crop such as coffee is healthy in a particular region, giving good yields every year without the die-back and exhaustion (which so often follow a bumper crop) and without being seriously troubled by pests and diseases, then it behoves an economic botanist to take careful note of the environment because it must be very near the ideal. There may be many regions where coffee can be grown in environments which are not ideal.

Other crops that have been in cultivation for centuries have been selected and bred to suit different environments and soils, and even in the wild state we find ecotypes which are useful to take into cultivation for local purposes. Little has been attempted with coffee until recent years. A start has been made to select for propagation purposes robusta coffees and Arabian mother trees which have shown themselves outstanding, and such acts as these will tend to form races adapted to the localities concerned. In general, however, the Arabian coffee plantations of the world have matured from seed, and have depended on the unaltered progeny of the original importations from Arabia.

There are two places that the author has in mind, both of which are in Tanganyika Territory. All the conditions of soil texture and substance, of moisture and humidity, of light and temperature must be in correct relation with the proper seasonal variations throughout the year to give such perfection as found here. It should, therefore, be enlightening to study the conditions prevailing in these regions.

Indications of Ideal Environment for Arabian Coffee

Kilimanjaro Mountain is a vast mound of land surmounted by two peaks, one of which is permanently covered with snow and ice, despite its nearness to the equator. The trade winds blow from the south-east, piling the rain clouds throughout a prolonged season against the south-western slopes.

Photo by author

Kilimanjaro mountain, over 19,000 ft. high, taken from Moshi town less than 3,000 ft high, showing the snow-covered peak of Kibo to the west and Mawenzi peak to the east. The coffee land is on the slope above the trees in the foreground, up to about 5,500 and 6,000 ft

PLATE X

By courtesy of Lt.-Com. P. C. Spink

(*a*) Kibo peak of Kilimanjaro mountain, showing the volcanic crater, looking southwards. Note how the cloud masses pile themselves against the mountain from the south-east, leaving the north-western slopes dry

(*b*) Young Arabian coffee at 5,000 ft., Kilimanjaro mountain, Tanganyika Territory. There is a sharp distinction between the seasons' growth. Branching is sturdy but not prolific. Note the cherry on the older wood. There are younger berries from a second flush near the main stem

Photo by author

PLATE XI

Arabian coffee has been planted by settlers and by Africans along the southern and eastern slopes from altitudes of 2,500 feet up to about 5,500 feet, but it is the south-east middle portion facing the winds where the coffee grows best of all. Furthermore, the ideal conditions do not apparently exist in this locality until an altitude of more than 4,500 feet is reached. Higher than 5,500 feet appears to be too cold, and consequently the area is restricted.

The chocolate-red volcanic soil is the same throughout—except in texture—and it is generally very deep. When the soil is bared to the sun at the lower altitudes it becomes dusty during dry weather, and glutinous and heavy during the rains. At the higher altitudes it is more stable and is doubtless affected by the equable climate, and the whole gamut of correlating factors concerned with moisture, humidity, cooler temperatures and a different soil cover. There are no earth worms there but the soil is undoubtedly fertile, and though leaning towards acidity, it is near neutral.

Rising a little above the semi-arid plains, the township of New Moshi lies at the foot of the mountain at an altitude of about 2,600 feet. Here, the seasons are more abruptly defined, and the rainfall is unevenly distributed; it falls mostly in the months of March and April and totals only about 28–32 inches, which is nothing like enough for coffee. The plantations at or near this level are never healthy. The coffee grows too fast and bears crops too early, always on the young wood, and the heavy yields in the third year lead to severe exhaustion and die-back. Thenceforward at least two years pass before another profitable crop is borne, and this is followed by progressive exhaustion and mis-shapen trees on account of the constant die-back of the lateral branches. Plantations have been heavily shaded by *Grevillea robusta*, which is the wrong shade tree to use with such a seasonal and short rainfall, as it is too greedy for moisture during the dry weather. Thrips then become a scourge, and at all times pests and diseases give trouble.

Progressively, at the higher altitudes on the south-eastern slopes the Arabian coffee gives better returns and a healthier growth. Up to an altitude of 4,500 feet, the land was taken up by European settlers during the German régime, when the country was known as German East Africa, and the coffee was all shaded under *Grevillea robusta*. Had the coffee been pruned in a different way, using the multiple-stem system instead of the single-stem, it would doubtless have given better returns. The plantations were laid down, often adjacent to each other, forming a continuous belt, and the trees were originally planted closely spaced, at not much more than six to eight feet apart.

Every step higher in altitude gives cooler temperatures, a higher and more evenly spread rainfall, and greater humidity, until at the 5,000 foot level there is a good deal of mist and low cloud. The coffee responds in a very noticeable way. It then bears almost entirely on the old wood and seldom on the green branches. So much is this the case that a main stem several inches in diameter is encrusted with berries so thickly that they cover patches of the bark from sight.

From 4,500 feet up to 5,500 feet, shade appears to be unnecessary, since the trees grow healthy and bear good crops year after year with very little exhaustion and much less fluctuation in yield. Pests and diseases are at a minimum and it would be trite to say that Arabian coffee is entirely at home. Temperatures are at times quite cold, with cold kabatic winds flowing down the valleys from the ice-capped peak.

Given a fertile, friable, and well-drained soil, it appears that Arabian coffee requires a cool temperate climate without frost, and without strong winds as well as a well-spread rainfall of not less than 75 inches, with mists and low cloud frequently mitigating the strength of the sun. For only a short while at these higher altitudes, i.e., from September to October, is the weather dry, but the heat of the sun still seems kindly on account of the humidity and the cool atmosphere.

The author wishes to belabour the fact that wherever Arabian coffee appears to find its proper environment, it tends to bear on the older wood and not on the young green branches. A full season would appear to pass before the younger wood flushes into flower, and this has a wonderful effect on the tree. A tree growing in a less suitable environment will flower on the young green wood, where flowers, immature green fruit, and fully mature red-ripe fruit will all be found at the same time among the leaves, needing more nutrients than the leaves can manufacture. Not only do the young branches then tend to shrivel and die back, with a resulting loss of crop and either empty berries or light beans, but the whole tree is robbed of nourishment at a time when it needs its full strength to bear the heavy successive crops. When the tree bears on the older wood, the leaves remain fresh and green while the crop is being borne; the crop matures in more regular fashion and the whole tree is healthier. As far as the author knows, the fact that Arabian coffee bears on its old wood in a proper environment, and on the young wood under adverse circumstances, has not been recorded by other observers.

Indications of Ideal Environments for Robusta Coffee, *Coffea canephora*

The indigenous distribution of robusta coffee often at fairly low altitudes, and in the humid and wetter regions of the West Coast of Africa, gives a general idea of the plant's requirements, but the author, here, is dealing with what appears to be an ideal, or very nearly an ideal environment in Tanganyika Territory, which he has closely observed for himself.

Most of the robusta coffee of Tanganyika is produced by African land holders in Bukoba district on the western shore of Lake Victoria. Bukoba is very near the equator, and the altitude at which the coffee is grown is approximately 4,000 feet. It is grown in a narrow strip of inhabited country bordering on the lake, where the rainfall is very evenly spread and totals 75 inches. Over a period of nineteen years, the mean temperatures were never less than 60° F., and were never more than 80° F., with very little variation throughout the year. (*See* Figs. 1, 2 and 3)

One might judge from a five-year period of experience at Bukoba that a little more rain might be beneficial, but the humidity and the even spread of rainfall thoughout the year may make up for this possible deficit. The temperatures would seem ideal, because they are so steady, and warmer than is best for Arabian coffee.

The fact is that the prevailing winds blow across the lake from the south-east. Cloudy and wet weather with violent thunderstorms is frequent over long periods of the year, and most of the rainfall is precipitated on the higher land above the lake shore, in a strip of country scarcely twenty miles broad. The humidity is soon spent, for the vegetation westward of this area merges into semi-arid thorn bush. The rainfall westward, in the uninhabited bush, must be little more than 25 inches, except for narrow strips of country along

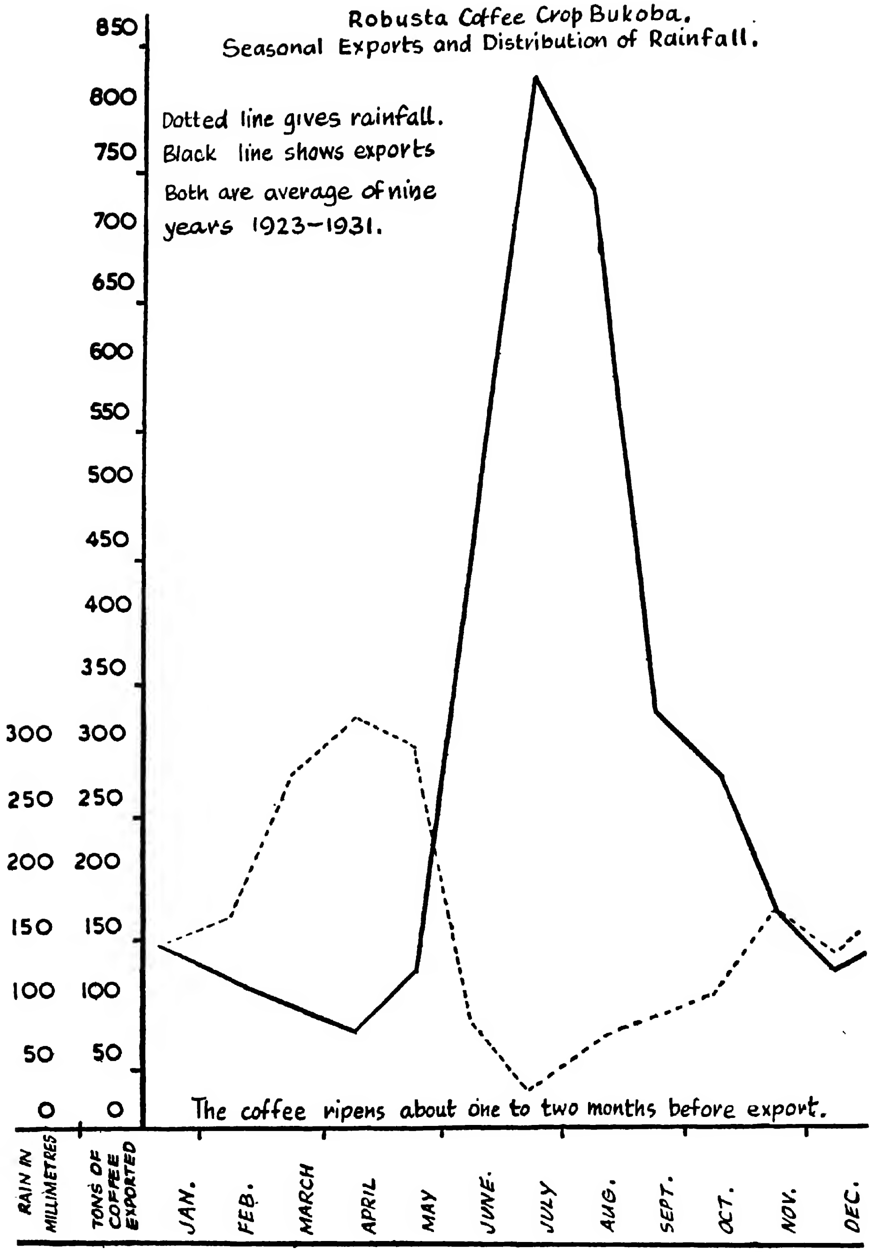

FIG. 1.—Robusta coffee crop Bukoba (compiled by author from local statistics).

the tops of inland escarpments where a few scattered inhabitants eke out a precarious existence. The region where the robusta coffee thrives, is very restricted.

In this region the soil leaves much to be desired, and in all the open grasslands it is most infertile. The grasses are wiry and tufted, and the cultivatable food crops are restricted to the earth pea or bambarra ground-nut, i.e. *Voandzeia subterranea* Thouars, and a tuberous *Plectranthus* sp. The soil is so 'dead', eroded, and useless, that none of the usual food crops will grow in widespread areas close to the lake shore.

The people have their banana plantations like islands in this infertile undulating land and these have been grown and tended on the same sites since the area was first inhabited. Constant mulching between the banana stools has kept the soil there in good heart, and moderately fertile, and it is in these banana plantations that the robusta coffee is grown.

To sum up, therefore, one might judge that the humidity and temperatures must be ideal, the rainfall sufficient, though more might be beneficial, and the soil is on the poor side even where the coffee is grown. Despite these drawbacks the coffee grows luxuriantly without proper attention, almost like a weed. It has been badly planted, much too close, and hacked about with axes and chopping knives in lieu of pruning. The menfolk of the tribe inhabiting the Bukoba district are lazy, and their practice of drinking banana beer at all times has blurred their intelligence and made of them a besotted people. The womenfolk, on the other hand, do all the work, and coffee growing has been forced upon them by their menfolk whose one aim has been to harvest the crop and take the profits for themselves. The womenfolk, who were never taught how the coffee should be grown, must look upon their coffee as an extra burden which brings little advantage to themselves.

The robusta coffee is very mixed in form and strain, though many of the trees have the branching 'Nganda' form. They grow in great dome-shaped bushes somewhat higher than the bananas, with a dense shade below. It is the soil shade and mulching with litter which has done much for their benefit. The author has seen a tree which had fallen down in early life but still lived, so that the orthotropic branches took root. In turn other branches took root as the tree covered more space, and new stems grew from the rooted sections until the single tree covered a circular soil space over thirty feet in diameter having as many trunks as a banyan tree. There are many instances of such tenacity and virility to be seen, and the trees bear good crops every year with a variation in yield depending mostly on climatic influences rather than on exhaustion following good seasons.

The soil in Bukoba district is a stiff, well-drained and slightly acid loam, covering hard sandstone rock where encrustations of iron pyrites may be seen. It is a brown loamy soil, rather than a chocolate-coloured one.

Growing among the robusta trees is a scattering of Arabian coffee, which, by its lanky growth and the bearing on the young wood indicates that the temperatures and humidity are too high for this species.

Coffee is an Evergreen

It is important to remember that coffee is an evergreen. Evergreens will exist in the driest country for one or more reasons. They must either be succulent plants like cacti with special provision for the storage of water and

constructed in such a way that transpiration is at a minimum, or they must have moisture in the subsoil and moisture-seeking roots which permit of transpiration occurring all the while.

In dry bush country there are evergreen shrubs entirely dependent on subsoil moisture; coffee is not a dry-land plant, yet it is an evergreen and as such it must have subsoil moisture all the year round. Everything points to the fact that if there is a deficit of moisture in the subsoil, coffee is unhappy and will not thrive as it should. It will be shown in other chapters, for instance, how weeds, cover crops, and temporary shade may create deficits of moisture to the detriment of the coffee, especially during the drier months or in regions where the soil is too light or the rainfall too short.

There would appear to be a contradiction in the fact that during a part of the year coffee requires the surface soil to become aerated and much drier. In other words the surface-feeding roots must be considered apart from the moisture-seeking roots in the subsoil. The surface roots require drier conditions for at least a part of the year, to permit the nitrogen content of the surface soil to be stepped up, and to slow up growth, ripen the wood and initiate flower buds. An indication of this is the fact that alternate row mulching has been found to give better returns and healthier trees than complete mulching. Also, mulching is definitely beneficial even though the mulch may be mostly decomposed and no longer efficient as a soil cover by the time the drier months begin.

It is most necessary to appreciate these vital points: that while a dry surface soil is beneficial for part of the year, it is imperative to have sufficient moisture in the subsoil all the year round.

Coffee Soils

A light soil is never suitable for Arabian, robusta or Liberian coffee, neither is a heavy clay desirable. Throughout the world coffee soils are generally friable and loamy of a lateritic or volcanic origin, and therefore brown, chocolate or red. In Brazil the 'Terra Roxa' or red soils are always chosen for preference.

A number of authorities have proved that a coffee soil should be slightly acid. Experiments in Brazil showed that a *p*H of between 4·2 and 5·1 should be the best for Arabian coffee.[6] Gethin Jones[9] stated that whereas coffee needs a slightly acid soil fairly rich in humus and available potash, it can manage fairly well on soils that are comparatively low in available phosphates.

Experiments with water cultures in Java and East Africa,[29 36] showed that neutral or weakly acid solutions were unsuitable. Symptoms of iron deficiency rapidly appeared even when iron humate was added to the solutions. Only in Shive's solution with an acidity of *p*H 4·5 did the plants develop normally. Mayne states[12] that while the results of water cultures must be treated with reserve, they suggest that the iron availability in the soil is very important to coffee, and if any alkalinity is present it may interfere with the intake of this important element. The most interesting indications arising from these experiments were the necessity for adequate supplies of calcium, the sensitiveness of coffee to iron deficiency, the intolerance shown to alkalinity and the importance of boron.

Experiments in Java showed that robusta coffee required an acidity in the soil higher than the *p*H 4·0 value and in the region of *p*H 4·5 to *p*H 5·0. The author[36] showed that calcium deficiency was not a real deficiency but a toxic

action of other elements in the absence of calcium. He states that robusta coffee exhibits potassium deficiency sooner than does Arabian coffee, that phosphate deficiency is also a little more obvious and that nitrate nitrogen has a much better effect on the growth of robusta plants than has ammonium sulphate.

The Roots of Coffee

It is only natural to expect that the root systems of coffee trees may vary to a degree according to the species and even to the varieties of each species. The interaction of a scion on a stock may also cause some modification. Beyond this, the methods of cultivation, the kind of soil and the amount and position of available moisture supplies, may alter the general plan of a plant's root development.

In general, coffee has a short and stout tap root, if it does not fork and produce several stout roots penetrating the soil to a distance of, perhaps, a couple of feet. It may generally be found that the more erect forms have a greater tendency to develop a distinct root than those that have a spreading and a shrubby growth above ground. Beyond these anchoring roots there is the close-netted table of feeding roots at and near the surface, with some of the roots tending to grow downwards in a friable well-aerated soil; also there are the moisture-seeking roots which Nutman in particular has found growing vertically downwards in a haphazard fashion from some of the laterals to depths of up to fifteen feet in the soil.

Nutman has carried out a great deal of study on the root systems of coffee[15 16], and the author, who has had much practical experience of coffee in East Africa, is in complete agreement with his findings. Nutman gives a general plan of what the root system is likely to be in a favourable rooting medium, and this in no way disagrees with findings elsewhere, even in localities considered to be the best for coffee, accountable, perhaps, to other influences than the soil.

A nursery seedling growing in friable nursery soil, and one that has never been transplanted, has moisture-seeking roots which can be traced downwards for several feet. It needs patience and great care to follow the thread-like tender roots to their extremities, and in ordinary planting practice most of these downward-growing roots are broken off. It is improbable that the general and natural structure would be recovered in the field after transplanting had taken place, except in the most favourable circumstances. Instead, a plant would tend to establish itself as quickly as possible by the extension of feeder roots in the soft top layer of the soil, and would develop moisture-seeking roots downwards as requisite, depending on the resistance given to penetration and on whether moisture supplies were sufficient or deficient in the surface layers.

In Nutman's general plan, gained by careful observation, axial roots are developed four to eight in number running vertically downwards below the trunk. They frequently originate from the laterals and penetrate to eight or nine feet, and branch in all directions at depth. The lateral roots are of two kinds: (*a*) those that belong to the surface 'plate' or 'table', and run more or less parallel to the soil surface to a distance of from four to six feet from the trunk, branching in a horizontal plane, some of which become geotropic and form verticals similar to the axial roots; (*b*) those which do not run parallel to the surface and ramify evenly and more deeply in the soil, sometimes become

vertical, and branch in all planes. The feeder bearers are of varying length, springing from the thicker roots and tending to be shorter and more numerous in the surface soil.

Hence there is often a mat or 'plate' of surface-feeding roots occupying a circle about eight to twelve feet in diameter. These roots are shorter and more dense, or longer and more loosely-branched according to the soil. At times coffee appears to be wholly surface-rooting because of the apparent absence of roots at depth occasioned, perhaps, by a difference in the subsoil or climatic influence. Well-spread or heavy rainfalls may render deeper roots unnecessary; there may be increased acidity at depth; or, as in Puerto Rico, heavy, uncharitable and moist clays, which, on account of the lack of aeration, the roots are unable to penetrate.

Surface development may be more marked in forest soils rich in humus in the surface layer, or the root system may occupy a small volume because the soil is a heavy loam, hard and compact. The aeration and drainage capacity of the subsoil must obviously affect the penetration of roots at lower levels, and in the event of a high water-table no roots have been found to approach the water nearer than 1 ft. 7 in.

In the 'Coloso clay' areas of Puerto Rico, which are poorly drained in the rainy season on account of a high water-table, Guiscafre, Arrillaga and Gomez found 94 per cent of the roots of Arabian coffee in the top 12 inches of soil, and almost all the other roots in the first 2 feet of soil. They admit, however, that some penetrated to a depth of 4 feet.[10] The pH averaged 4.6, and the authors concluded that coffee was a surface-feeding plant and that care should be taken not to mutilate the surface roots during cultivation.

It might be advisable to mention here that feeding is different to moisture-seeking, and in the event of the surface roots being constantly supplied with enough moisture, or the water-table being sufficiently high, there is no need for the plant to develop moisture-seeking roots at all. There appears to be considerable controversy in the literature as to whether coffee plants develop deep roots. Obviously they do so when the need arises, and no one investigator can lay down the law on the findings in his own locality.

The same authors[11] who, by the way, have not entered into such a controversy, also investigated the rooting system in what they call the Catalina clay region of Puerto Rico, one of the most extensive lateritic soils found in the island, and of importance in its coffee-growing regions. The rainfall is in the neighbourhood of 70–75 inches per annum and the soil is well-drained down to a depth of 3 or 4 feet. All the layers of soil showed a pH value of 4.98.

In the Catalina clay, 95 per cent of the roots were found in the top 12 inches, 4 per cent down to 2 feet, and 1 per cent in the remaining layers down to 4 feet. The authors also investigated the range of roots of twenty-one-year-old trees in the same region and found similar percentages, though in this case they did remark that 'roots in the 84- to 96-inch layer were negligible', indicating that a few may have reached this depth.

As for the feeding roots themselves, these become active and grow fresh absorbing tips which remain alive or shrivel in accordance with seasonal influences, or remain active all the while under certain favourable circumstances. Their activity must be reflected in growth or dormancy above ground, and become more noticeable during periods of soil aeration when nitrogen formation is at high peaks. Several authors discuss these points, for the activity depends upon environment, and it is necessary to know when the

feeding tips develop so as to avoid disturbing the roots at these times. When the roots are actively feeding, surely this must be the time to apply fertilizers, or does the application of fertilizers tend to encourage feeding activity? It may not be wise to encourage such activity too greatly for it might tend to produce growth and leafage above ground at a time when the flower buds are being initiated.

Wakefield[37] states that the approximate periods of growth at the medium altitudes in the Northern Province of Tanganyika are as follows: New shoots and leaves are developed from March to June and from September to December, activity being most noticeable in April and November. The active growth of feeding rootlets takes place mainly during the drier months between December and the following March, and he states that it is obviously unwise to disturb the soil during this period of activity. He argues that the plant elaborates and stores food for further use; in other words, such activity takes place prior to the harvest season and not necessarily during shoot growth above ground. He advises that the best time to apply fertilizers must be at the beginning of root activity.

Naturally if the surface soil is too dry, or when a bare soil becomes heated to a high temperature by the sun, then root action will cease. Thomas and Martin[32] state in relation to robusta coffee in Uganda that during the dry season, which is more pronounced in Uganda, active root growth ceased except in soil under mulch. On hot afternoons the soil temperature at a depth of two inches under the mulch was found to be 50° F. lower than that of clean weeded soil nearby. Shade and soil shade must therefore be of great importance in regard to environment.

Root-feeding activity may vary in different localities in accordance with soil aeration and periods of drier weather. It may possibly be prolonged by shade and cooler temperatures and also by mulching, provided the soil is not rendered too wet for a longer period after the end of the heavy rains. It is in this connexion that we may find the reason why alternate row mulching is better than widespread mulching or no mulching at all.

Some planters appear to think that in the drier areas of Kenya where rainfall is short, the feeding roots of coffee should be forced to a lower level. 'The sooner the coffee is trained to feed deeper where there is some moisture the better for it and its owner,' they say, and go on to record how tractors with tandem disc harrows have been used for years cultivating to a depth of five inches twice yearly so that 'it is impossible to find a feeding root near the surface—yet the coffee has not suffered'.

The truth is that they do not know how much it has suffered in the absence of proper experimental tests and control plots. It might well have been better to leave the roots to find their own limit of endurance to drought and heat, and the correct procedure would be, of course, to mulch the soil. In fact, the cultivation of the soil in mature coffee orchards must be as little and as infrequent as possible.

Shade

More will be found in the chapter on shade, which is artificially arranged for in plantations by the planting of shade trees. In the southern valleys of the Abyssinian Mountains at the higher altitudes, Arabian coffee is said to grow naturally on the banks of streams and in forest glades. Robusta coffee forms a fringing growth or an undergrowth in light rain forests and glades

where there is at least root shade and ample moisture. Liberian coffee is said to be able to stand more light, but it is also a shade-loving plant with its feet in shade and a moist soil. Alone among these coffees excelsa is depicted as growing in small groups of big trees in open semi-arid country, or in the drier forests of Northern Uganda.

The light intensity is diffused by shade. The soil is kept cool by the shade, by the carpet growth, and by the litter which is provided from above, though there is never so much litter beneath evergreen trees as there is in a deciduous forest. However, one can well imagine how the soil must breathe again in the localities where these coffees grow wild, after a prolonged period of rain, and when the air seeps into the soil again, root activity must then be at its peak. There is a constant activity on a reduced scale when feeding rootlets emerge from the soil and wander among the wet, decomposing but aerated litter lying on the soil surface. It is all a pretty picture which one imagines must be true, and if one reproduced these exact conditions on a plantation one might well get the same returns—healthy growth but not very big crops of fruit.

On a plantation it is necessary to give the plant the essential necessities for healthy life and yet coerce it into bearing more fruit. Shade tends to depress yields if it is too dense.

If tropical rain is heavy and continuous, it does not tend to encourage growth during the wet season, for the soil becomes saturated so that soil life is at a standstill and nutrients are leached from the top soil. The rains provide moisture to the subsoil thus replenishing the reservoir on which plants depend during the drier months. Though there is transpiration from shade trees the loss is more than balanced by a reduction in transpiration by the undergrowth and of evaporation from the soil, though if this were its only advantage overhead shade could be dispensed with provided the soil shade remained.

Since overhead shade diffuses and reduces the light intensity for plants growing underneath, it has another vital influence. The light intensity may, however, be reduced to a sufficient degree in those localities where there is much mist and cloud—the reason why coffee may flourish without shade in several regions of the world.

Nutman has shown that the rate of assimilation remains fairly constant throughout the day while the weather is cloudy, whereas there is a large depression during the midday hours in full sunshine.[17] The assimilation rate changes very rapidly, and it appears to vary directly with the light intensity when this is low, the rate being reduced when the light intensity is high.

The assimilation rate of Arabian coffee is greater under conditions of moderate light intensity than in full sunshine, and the total daily assimilation is greater in the shade than in the sun. In full sunshine, therefore, the assimilation rate drops from about 9 a.m. until 3 p.m. each day.

Nutman was forced to the conclusion[18] that light radiation exercises a two-fold action on the leaf stomata of coffee. At low intensities the stomata open, but high intensities—in other words, too much light—cause the stomata to close. This is not due to changes in the water content of the leaf, although closure can be induced by water shortage in the normal way.

Stomatal movements can control assimilation by varying the rate at which carbon dioxide is supplied to the chloroplasts, and though carbon dioxide can enter a leaf by diffusion through the cuticle, coffee has coriaceous leaves and it is improbable that any appreciable diffusion could take place in this manner.

Erratic Rainfall

Attention has been drawn in the Lyamungu Research Station Reports, Tanganyika Territory, to the fact that though the average annual rainfall would appear to be satisfactory, the separate yearly returns show wide divergence, as will be seen in the following tabulated returns. Such a variation from year to year is not good for coffee, and the figures prove how necessary it is to study the rainfall and not place too great a reliance on averages.

The average annual rainfall at 400 feet higher in altitude than the Lyamungu station is eighty inches, and though the same variability may be found, the fall during the drier years is then sufficient, while that during the wet years is not too much.

During 1951 in Kenya, an exceptionally wet year, a study of the local variation in rainfall was made, and results are recorded in the annual report of the agricultural chemist (coffee services) for 1951. A line of six standard 5-in. diameter gauges was sited along the main ridge of a 380-acre estate. The highest gauge, No. 6, was some 70 feet above No. 1, the lowest, separated from the other by three-quarters of a mile. Nos. 2 and 3 were placed together, but No. 3 was surrounded by a sloped embankment in order that turbulence caused by the body of the rain gauge should not disturb the air-flow across its mouth. The annual totals are shown in the table, where it will be seen that the readings of single rain gauges differ by 3.42 in. and 39 wet days in the year. Such a local variation is important, and might be much greater on any one estate where the slopes and aspects of parts of it differed greatly from each other.

Gauge ...	1	2	3	4	5	6
Inches ...	54·05	56·33	56·18	57·17	57·47	56·99
Wet days ...	200	200	203	204	204	165

The rainfall of Kenya is notoriously short, and in a short rainfall area a loss of more than three inches in the year is a serious matter. We all know the vagaries of the weather; how a shower in the tropics can wet one end of one's residence and not the other. A curtain of rain can be seen falling on one part of an estate and not elsewhere, and by closely observing the direction taken by rainclouds throughout a period of years it will be seen that they often appear to follow the same course.

Even in this wet year in Kenya, a rainfall averaging 56 inches was not sufficient without mulching. Tests for soil moisture were made in the layer between the 6-in. and 9-in. depths in the soil to discover the duration in days during the year when the moisture in the soil was at the availability level.

	Fallow land	*Planted with coffee*
Days of available moisture—Bare soil	225	180
Ditto—under Grass mulch	305	310

Thus in spite of a favourable year in which rain fell on 165 days, the mulched coffee was able to benefit by an extra one-third of a year of available moisture in this important horizon of top soil.

RAINFALL LYAMUNGU

TANGANYIKA TERRITORY

	1938	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*1948*	*1949*	*Average in Inches*
Jan.	0·52	0·22	2·83	1·23	1·59	0·07	1·02	1·72	0·02	2·01	0·46	1·79	1·12
Feb.	2·43	0·41	5·27	1·91	0·38	2·61	1·69	1·39	1·14	0·72	0·71	4·17	1·90
March	12·42	4·57	4·12	2·38	15·02	1·32	5·82	4·85	0·57	3·37	2·72	0·10	4·77
April	10·79	26·18	21·63	15·02	37·07	7·95	30·04	15·19	16·90	28·45	14·50	9·34	19·42
May	19·44	25·31	12·04	10·24	19·43	19·46	11·97	21·34	22·74	25·73	15·56	10·64	17·83
June	2·61	8·74	2·68	5·09	4·54	4·06	4·65	3·45	2·54	10·97	2·93	0·92	4·43
July	1·92	0·77	2·04	0·76	2·38	4·42	2·21	3·15	0·50	1·43	1·53	1·86	1·91
Aug.	0·67	0·54	2·58	2·10	1·22	0·37	1·43	1·33	1·03	1·38	0·44	0·82	1·16
Sept.	0·17	1·61	0·33	2·76	0·11	0·49	2·42	0·20	7·34	1·23	0·30	0·33	1·44
Oct.	2·16	0·08	1·03	0·09	0·42	0·17	3·15	0·05	4·71	1·27	2·51	0·69	1·36
Nov.	2·57	0·57	0·90	4·47	3·60	2·00	3·10	4·66	1·13	0·93	1·65	0·26	2·15
Dec.	1·02	0·32	1·07	9·72	1·75	0·32	5·14	0·30	2·19	1·31	6·19	1·38	2·56
Total Inches	56·72	69·32	56·52	55·77	87·51	43·24	72·64	57·63	60·81	78·80	49·50	32·30	60·05

Note.—The annual fluctuations are extraordinary and in general the rainfall is short.

LYAMUNGU TEMPERATURES

Year	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
						MINI	MUM					
1936 ...	15·1	15·4	15·2	16·1	15·3	14·3	13·3	12·4	13·0	12·5	14·0	14·5
1937 ...	14·6	14·6	15·8	16·1	15·7	14·5	13·3	13·0	13·2	14·6	14·8	15·2
1938 ...	14·0	14·8	15·6	15·5	15·2	14·0	13·1	12·3	12·7	13·5	14·0	14·8
1940 ...	14·8	14·6	15·5	15·8	15·6	13·9	13·4	13·3	12·6	13·4	13·9	14·4
Means. Centigrade Fahrenheit	14·6 58·3	14·9 58·8	15·5 59·9	15·9 60·6	15·4 59·7	14·2 57·6	13·3 55·9	12·7 54·9	12 9 55·2	13·5 56·3	14·2 57·6	14·7 58·5
						MAXI	MUM					
1936 ...	26·1	26·1	26·1	23·4	21·6	20·1	19·7	20·9	22·6	26·2	27·9	27·6
1937 ...	28·6	29·9	27·6	23·0	21·7	20·3	20·5	21·3	24·3	23·8	26·3	26·5
1938 ...	29·3	29·3	27·4	24·3	21·5	20·6	21·4	21·2	23·6	25·9	26·0	25·7
1940 ...	28·1	29·2	26·1	23·7	22·3	21·4	20·6	21·9	24·2	26·5	27·9	28·8
Means. Centigrade Fahrenheit	28·0 83·4	28·6 83·5	26·8 80·2	23·6 74·5	21·8 71·2	20·6 69·1	20·5 68·9	21·3 70·3	23·7 74·5	25·6 78·1	27·0 80·6	27·2 81·0

RAINFALL IN INCHES

Kilimanjaro

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total Average*	*Altitude*
Lyamungu	1·12	1·90	4·77	19·42	17·83	4·43	1·91	1·16	1·44	1·36	2·15	2·56	60·05	4,400ft.
Machame	2·30	3·80	4·70	25·80	20·00	8·40	5·00	2·30	1·00	1·80	2·30	2·70	80·00	4,800ft.

Note.—Machame records are average of 10 years, Lyamungu of 12 years. The figures show the difference in rainfall at 400 feet higher up the mountain.

TEMPERATURES

The fact that the chief economic species of coffee grow indigenously in shaded places, or in neighbourhoods where there are prolonged periods of rain and cloud, indicates that they require air temperatures a great deal less than would be found in full tropical sunshine under clear skies. Furthermore, shade tends to even up temperatures by reducing the day temperatures and resisting the fall of night temperatures. More important still is the fact that the soil temperatures need to be cool, and kept within bounds, as would happen in a state of nature where coffee is found growing wild.

There is every indication that successful coffee production is closely tied to temperatures within limits which can be defined. Temperatures that are above the optimum for Arabian coffee force a rapid growth, early bearing, overbearing on the young wood, early exhaustion and die-back. When temperatures are too cold, Arabian coffee grows slowly and stunted and becomes uneconomic, while cold winds may blacken, distort or shrivel the shoot tips and cause what is known as 'hot and cold' disease. Arabian coffee will stand periods of cold weather near zero, but it is severely damaged by frost. A hot bare soil which inhibits feeder-root activity in the surface layer undoubtedly hastens exhaustion and increases die-back.

It would appear that robusta and Liberian coffees will stand warmer air temperatures during daylight provided the light is diffused, but they grow best within narrower limits and are harmed by cold weather. It is interesting to take notes of the temperatures in some of the important coffee-growing regions.

Ukers states that the average temperatures in Arabian coffee-growing regions are 55° F. minimum, 80° F. maximum and a mean of 70° F.[34] At Balehonnur in India where both Arabian and robusta coffees are grown the temperatures range between 63.7° F. minimum and 80.2° F. maximum,[1] whereas in Kenya the diurnal difference is often wider than this. In the most favourable area for Arabian coffee in Tanganyika the temperatures range between 55° F. and 70° F., whereas in the best robusta region they are 60° F. minimum and never more than 80° F. maximum.

In Mexico the temperature does not fall below 50° F., and it ranges on an average from 60° up to 77° F. The best climate in El Salvador is said to have temperatures ranging from 57° to 70° F., while the usual temperatures in the coffee-growing regions of Venezuela are 59° F. minimum and 68° maximum. In some Venezuelan regions, however, the temperatures mount as high as 90° and recede as low as 46° F.[7]

On the central plains of Costa Rica the average mean temperature is about

68° F. but there may be peaks, it is stated of 97°, and falls to near frost. The average temperatures in Colombia in the best coffee-growing regions range from 60° F. to 72° F. As for Brazil, it is well known that frosts may occur during the winter season, and the coffee grows best when it escapes frost but when the temperatures do not mount too high.

Air temperatures may be mitigated by overhead shade, and ground temperatures may be lowered still further by mulching. There is a danger that sprinkler irrigation used in hot weather in combination with a mulch might lower temperatures too far on account of a rapid evaporation.

Maintenance of Environment

By comparing environmental details in the regions where coffee grows well, with those which seem needful in their wild habitats, we may arrive at and find a correct set of correlating conditions. We may find the right soil, shade, light, temperature and moisture conditions throughout the year for economic coffee production, and straight away begin to clear land and plant coffee. No sooner do we do so than the environment begins to change. At least one of those conditions cannot be given in a state of cultivation until afterwards, i.e., the shade. Environment on a coffee plantation must therefore to some extent be man-made, with a fore-knowledge of the requirements.

When once by dint of hard labour and wise choice we have obtained the correct environment, then it must be maintained. It is this maintenance which has not taken place in many parts of the world.

Brazilian coffee planters have been particularly backward in this respect, for they have ruined their soils and done little to prevent erosion and deterioration until the land used in the past became no longer fitted for economic cultivation. Neither have British coffee planters in East Africa been faultless in this respect, for the practice of clean cultivation has ruined many a coffee estate in Uganda and Kenya.

Biggs quotes from cultural experiments in Uganda where evidence was produced of the combined effects of erosion and the abnormal combustion of organic matter when a soil lacked cover. The loss over a three-year period was enough to change the soil conditions and the economy of the crop.[4] Pereira and Jones say[20] that the loss of organic matter from cultivated top soils is so rapid in the hotter and drier coffee areas that progressive planters require no convincing of the need to arrest it by every practical method of husbandry.

Erosion and lost structure lead to other changes in environment such as the ability of the soil to absorb moisture. By permitting weed growth, cover crops, catch crops or temporary shade plants to grow among the coffee in dry areas or dry seasons, the environment may be altered to the detriment of the coffee by creating moisture deficits in the subsoil. In many ways can an optimum environment deteriorate by using unwise or careless methods of husbandry, until it is no longer fitted for a permanent crop of orchard trees.

Many growers in Kenya endeavoured to maintain the fertility of their soils by buying cattle manure and spreading it round their trees. The manure from cattle kraals was not of high value, and it was expensive to buy and spread. Moreover, the application of the small organic dressings which could be afforded proved ineffective in so far as any improvements in yields were concerned. Similar results were obtained in India.

Temperatures reached on uncovered soil can be remarkably high. Tem-

peratures of over 140° F. in the top centimetre of soil have frequently been observed at 5,700 feet altitude at Kabete in Kenya, and on 75 per cent of all days the surface soil temperatures exceeded 100° F.[20] How much greater must be these temperatures at lower altitudes. It is vital to maintain the cool soil temperatures required by coffee, by mulching or shade.

Physiology of Growth

The different economic species of coffee have forms which are comparable in many ways, and the general plan of growth is much the same. We have the upright growing orthotropic stems which do not alter their nature, and in the axils of the leaves of these uprights we have two kinds of buds, one above the other. The lower buds are called accessory.

The upper buds produce lateral growths and these arise on opposite sides of each node in succession, as the growing tip of the upright is prolonged. While this tip does not appear to exercise control over the lateral growth, it may exhibit a restraining influence on the accessory buds, for these do not normally awaken into life until the topmost growth of the upright is damaged, or it is bent out of its natural position and arches downwards. Then, and then only, do the accessory buds begin to grow uprights which find themselves springing rather awkwardly from beneath the laterals, so that they have to curl round them if the main stem is still upright. Doubtless the accessory buds are arranged in such a position because the stems of coffee often do arch over in a state of nature.

The lateral bud on the main stem is always a single one, for if the lateral dies back or is cut back to the upright, there are no other buds to produce new laterals. It seems that further accessory buds can be initiated, however, if the first to sprout is gently rubbed away, so that more than two orthotropic growths can spring from each node. These accessory buds on the older wood and even on the main trunks of Arabian coffee trees, appear able to alter their potential and become flower buds in place of shoot growths in some environments. They permit the older wood of a coffee tree to become encrusted with berries, and bear cushions where flower buds may perpetually be initiated rather like those to be found on a Cacao trunk. In other environments they do not form at all, and flower buds are initiated only on the young laterals.

Van Der Meulen[35] mentions that excelsa coffee flowers considerably on its old wood, and the blossoms arise in the axils of leaves which in most cases have been shed. After flowering, the vegetative points may persist so that flowering may take place again in future years. This, he says, does not happen with the robusta coffees. The author of the present work does not remember seeing *Coffea canephora* flowering or fruiting on its old wood.

The laterals which are often called 'primaries', will grow 'secondaries' and 'tertiaries' in time, the secondary buds also arising in the axils of the leaves. It would appear that there are accessory buds also on the laterals, but these do not develop into upright or orthotropic growths. All are plagiotropic, and the function of the branch accessories is to multiply and produce clusters of flowers. Both these secondary buds and the accessories to them will produce flower buds it seems, and if an impetus is given to them to produce shoots, then all can develop shoot growth at the expense of flowers. Immature floral buds are indistinguishable from those which may give rise to secondary shoot growth.

By courtesy of L. W. Kerham, Esq

Coffee country at 4,500 ft., Kilimanjaro mountain, with a plantation of Arabian coffee in the middle distance. Note the broad-leaved herbage, and the banana leaves indicating the absence of strong winds

PLATE XII

Photo by author

(*a*) Robusta coffee in wrong environment, Tanganyika Territory. Note the dry thorn bush, the absence of erosion protection, cultivation or shade. This plot of coffee will never be economic

Photo by author

(*b*) Robusta coffee badly planted on an exhausted patch of banana garden The effects of poor soil, bad planting and no shade Bukoba district, Tanganyika Territory

PLATE XIII

Too much pruning will tend to produce shoots at the expense of flowers, and when Antestia bugs puncture the young shoots and buds, then a multiple growth is produced resembling the phenomenon known as 'witches' broom'. Several authorities state that when Arabian coffee is grown at a high altitude in a situation that is cold, the bushes then exhibit a prolific branching habit. This is not the author's experience if the moisture conditions are satisfactory. It may be the case where the temperatures are low but the rainfall is short.

Rayner[24] states that a balanced ratio between leaf and crop is one of the basic considerations for good coffee growing. He records that the axillary buds on lateral branches are produced in a series, the largest and most differentiated being nearest the stem to which the leaf is attached and the smallest nearest the leaf stalk; the buds of intermediate size are situated between the two extremes. There are usually three buds in the series visible in the axil of a leaf which has just separated from the terminal bud of the branch on which it is produced. They are not usually visible, however, until the two scales or interfolia stipules surrounding the stem at the point of insertion of the leaves have been removed. Later a fourth or fifth and even a sixth bud may be added to this series, though three or four are the usual numbers.

The members of the bud series may eventually grow into vegetative shoots or they may form inflorescences, and there may be up to six inflorescences developed in each leaf axil. Usually the inflorescences consist of four flowers borne on short stalks attached to a main stalk, two above and two below in alternate pairs. If more than four are formed, then there may be a further pair below and a terminal flower above. The base of the inflorescence stalk is wrapped in two to three pairs of scales which are rudimentary leaves with their interfolia stipules, and these may occasionally form small recognizable leaves below the flowers. Small buds are present also in their axils, and these may develop as late flowerings, or into further inflorescences. It seems that there are always some dormant and undeveloped buds remaining after flowering, and these produce flowers and shoots in subsequent seasons. Sometimes all except one flower bud of an inflorescence remain dormant. The first member of a bud series normally develops the largest and earliest inflorescence, while the next in the series produces a later and smaller inflorescence.

Rayner explains that a number of the first members of the bud series on a lateral branch always develop into secondary vegetative shoots, and sometimes a second member of a series may also develop into a shoot. When the stimulus to produce vegetation is very strong, even the third and fourth members may give rise to shoots so that a fan of new secondaries may be produced. It is not possible to determine by external observation whether a bud in its early stages is likely to produce a flower inflorescence or a shoot, though the elongation of a bud may later provide a clue to the fact that it will become a shoot and not a flower.

The axillary buds appear to grow continuously from the time they are first initiated in the terminal bud until flowering takes place in between seven and ten months' time. Generally, however, there are two periods of growth separated by one of dormancy. The first is from formation until the first member of a bud series is just visible among the interfolia stipules. Then, after a period of apparent dormancy which may last up to ten months, the buds start visible growth again until flowering. On the other hand, buds which will form vegetative growths may grow rapidly from initiation into a

definite shoot in three to four months, though there may be periods of dormancy similar to, or longer than, that of the inflorescence buds.

In those situations where the berries are mostly borne on the young wood, the rate of growth of the whole tree is reduced while the crop is being borne, and the tree only recovers its rhythm of growth in the following 'off' years while recuperating its strength. The low yield in the following year is partly attributable to the fact that the new bearing wood has been reduced.

In India if the rains start well about mid-March, there is a single blossoming period at the end of March or in early April; but a poor rainfall at this time causes several blossomings over a period of a couple of months, usually resulting in poor crops.[13] The flowers open approximately nine days after a shower of three-tenths of an inch or more. A rapid shoot growth begins, and most of the annual vegetative growth takes place at this time, slackening towards the end of May and earlier if there is a heavy crop. Fruit development accelerates as the growth slackens and continues to the end of August, until vegetative growth is at a standstill in June and July. Growth begins again in August and continues through September and October. The dry season begins at the end of November and stretches until mid-March, and it is during this time that the harvest and the post-harvest resting periods occur.

This resting period is dry and cool when growth is at a minimum. The differentiation of the flower buds is active after the crop has been gathered, and when the temperature rises towards the end of this period, vegetative growth may begin again even though no rain has fallen.

With Arabian coffee, growth is prevalent in the big rains, and may be curbed when the trees bear big crops— in other words, when they overbear their strength. There follows a period of slow recuperation during which growth is not active at first, but may be encouraged by certain factors at the expense of bud ripening for the next year's crop. Warm temperatures, coupled with ample moisture in the surface soil, will cause more vegetative growth instead of the short period of dormancy which appears to be required. Irrigation at the wrong time, a mulch which is maintained too thickly throughout the year, and too much manure might each throw the coffee plant into too much vegetative growth at a time when the flowering wood should be ripening. Profuse flowerings take place after a comparatively dry spell when there has been little vegetative growth.

Portères[22] carried out observations on the effects of rainfall after a dry spell in French Guinea where there are two clearly marked seasons in the year, i.e., a long rainy season and a short dry one, a circumstance which he says results in a corresponding well-defined period of flowering. He recorded that rainfall in excess of 3 mm. was sufficient to induce blossoming. All buds open on the same day, he says, whatever their initial size or the quantity of moisture received above 3 mm., but the number of buds that develop is roughly proportional to the precipitation.

A single fall of rain may be sufficient to cause several successive blossoming periods, and light showers, though they may be insufficient in themselves to induce blossoming, may by their cumulative effect cause the buds to flush and the flowers to open.

The time taken for the flowers to open after sufficient rain has fallen varies from about nine to fifteen days according to environment, and it would appear that temperatures are interrelated with moisture conditions to shorten or lengthen this period.

In Uganda there are two seasons of rainfall, i.e., the big and the short rains, with intervening periods of drier weather. At the lower altitudes Arabian coffee flowers twice a year with smaller scattered flowerings at odd times, and it is this that undoubtedly makes the environment there somewhat unsuited to Arabian coffee culture. It leads to exhaustion because the trees never have sufficient time to recuperate their strength.

It appears, therefore, that though the economic species of coffee require a well-spread rainfall during which growth may take place and the fruit may set and swell, a short dry period is required following the harvest when the surface soil at least can become drier. There must never, however, be a deficit of moisture in the subsoil. Coinciding with the drier period it is best for Arabian coffee to enjoy cooler temperatures than occur during the growth periods.

Thomas[33] observed the growth of robusta coffee in Uganda and found that the trees made most of their growth in the dry season. He found that growth was correlated entirely with crop production, and that the time of crop ripening had a most important bearing on the vegetative growth of the trees. Growth occurred in the dry season because that was the time when the trees were bearing very little crop, for young bushes which had not started to fruit made most of their growth during the rainy season, and self-pollinated branches of older trees which bore no fruit would continue to make growth while adjacent branches bearing a heavy crop made no new leaves.

The early ripening of the crop on the spreading *nganda* variety of *Coffea canephora* in Uganda is the secret of its vigorous growth in a normal year, since the fruit is removed by December and the trees have two months in which to grow before a new crop of berries is set at the end of February or March.

It must be remembered that the rainfall of Uganda might be considered in general very light for robusta coffee, and that growth must be altered by a moister environment.

Rayner[25] states that the principal flowering in Kenya usually occurs at the onset of the long rains, and that the development of these flowerings is possibly dependent on growth during the short-rains of the previous year. A series of experiments have shown that the point in the development of a flower bud after which it is no longer possible to make it change to a vegetative one, occurs during the period of minimum growth, which in Kenya is during the months of June to September, and again for a shorter period during January and February. Provided the buds have not passed a certain morphological stage, which occurs a month or so before flowering, they can be changed into vegetative shoots by pruning away the branch above their point of insertion.

Pruning might therefore take place after flowering if a tree has ample vegetation, or before the buds become determined as flower buds, if the tree has poor leafage and it is desirable to reduce the crop; this will depend, of course, on the environmental effects of temperatures and rainfall. (Figs. 2–3)

As Van Der Meulen[35] points out, coffee shows a flowering rhythm in regions where rainfall is abundant, which is quite different from that where the seasons are sharply separated into dry and wet periods. Then again, species and their varying forms differ as to their growth and flowering even in the same climate.

He states that some robusta coffee varieties in Java make extensive growth after the rains have started, but flowers do not appear until about the middle of the second half of the rain period. About the end of the rains the flowering

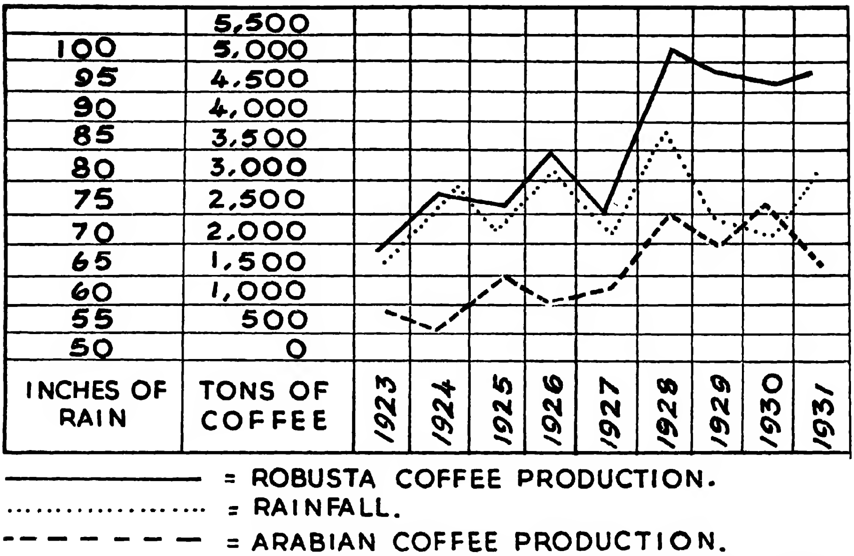

FIG. 2.—Graph made by the author from statistics available during his residence in Bukoba District, Tanganyika Territory.

is at its height, and about two months after the dry season has set in, flowering comes to an end. Other varieties of robusta start flowering earlier in the first part of the rainy season but end about the same time.

It would appear, therefore, that there is this difference between Arabian and robusta coffee. The Arabian coffee flowers shortly after the first showers of the long rains, while the robusta flowers a month or two after the rains have begun. The author observed in Bukoba, Tanganyika, that the years of peak yield with robusta coffee coincided with exceptionally heavy rains in the same crop season. Whereas the yield of Arabian coffee fluctuated on account of overbearing and exhaustion, the returns of robusta coffee closely followed the annual precipitation.

Mayne[14] has shown that there is a close relation between the number of flower buds present at blossom time and the number of leaves present on the same branches. His figures indicate the great importance of leaf area, and suggest that supplies of carbohydrates determine the crop size of Arabian coffee.

FLOWER BUDS AND LEAVES ON 100 CROPPING BRANCHES AT BLOSSOM TIME. ARABIAN COFFEE.

Year	*Buds*	*Leaves*	*Buds/Leaves*
1931	9330	832	11·2
1932	5380	405	13·3
1933	6946	540	12·5
1934	5310	437	12·2
1935	3054	347	8·8
1936	6130	600	10·2

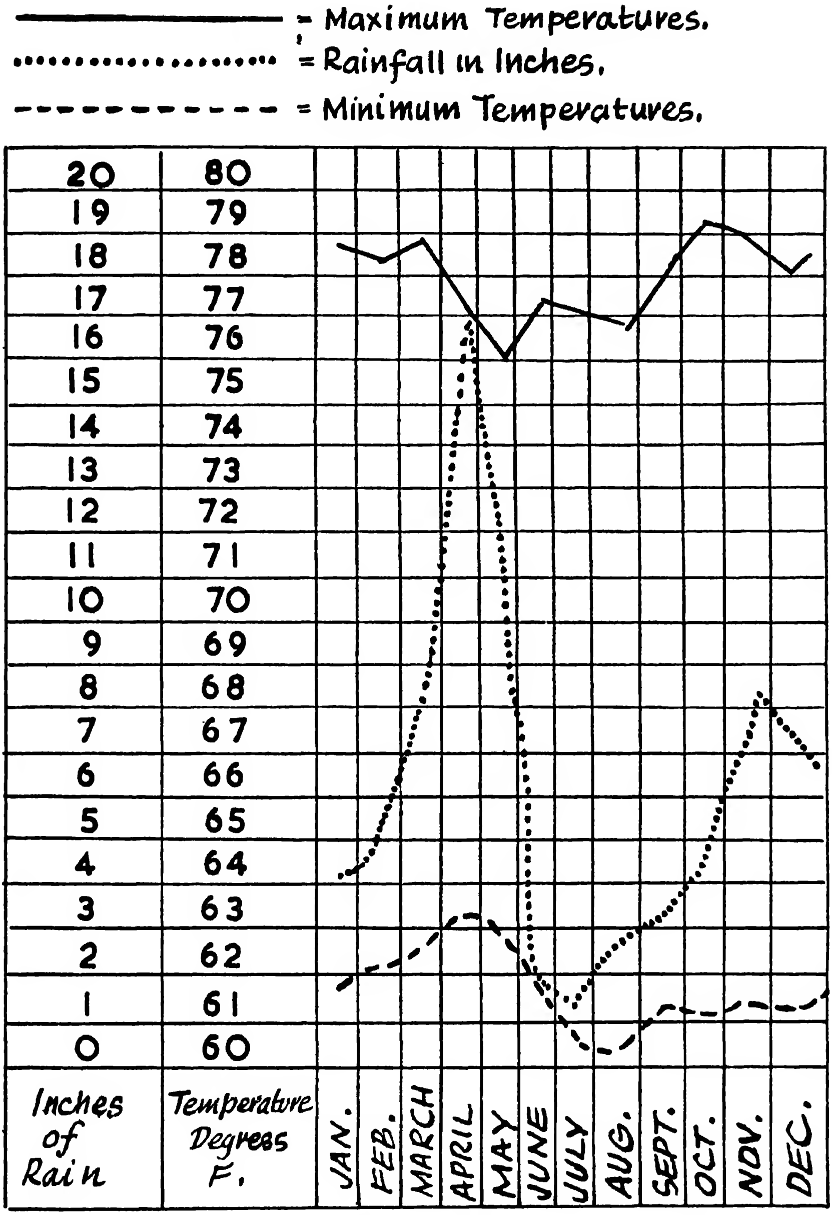

FIG. 3.—Monthly rainfall and temperatures, Bukoba District, Tanganyika Territory. Averages of 9 years' recording. Taken from figures, pamphlet No. 2, Department of Agriculture, Tanganyika Territory.

Mayne also studied fruit set and discovered that the set was variable in different years in the same locality, as might be expected. He found that the setting is subject to three clearly defined periods of loss, and that the losses of fruit in the later stages of development are very small if there are no factors such as diseases and pests affecting the vegetative growth. The variation in setting appeared as a rule to occur in one or the other of the group periods of loss, rather than to be distributed over all three groups.

	1931	*1932*	*1933*	*1934*
Original flower buds	9031	5379	6768	5310
Loss % first 4 weeks	20·5	26·2	26·9	20·0
Loss % 5th to 11th week	38·3	27·0	26·6	27,5
Loss % 11th week to harvest	4·2	4·5	7·9	22·5
Crop harvested %...	37·6	41·4	38·6	30·5

A certain number of young fruits never develop into mature berries but remain for varying periods up to harvest very little larger than they were shortly after flowering. Until the fourth week it cannot be told whether all the fruit initials have set, but by the fifth week the set fruits are a little larger than the unset ones which sometimes persist until harvest. The second period may be defined by the ending of a very marked loss which occurs about the eleventh week. A number of the partly swollen fruits which appear quite healthy may then be shed. Mayne thinks that most of the early loss is unavoidable and due either to incomplete fertilization, or to competition for the nutrient supplies.

Nutrient Flow

Obviously the availability and flow of nutrients must affect the health and yield of coffee. The trees obtain their moisture from the soil, and to some extent they may absorb moisture through the cuticles of their leaves, or through their leaf stomata in an atmosphere which is very humid. Sufficient moisture is a first essential and naturally of greater importance at certain times, when growth is exuberant, and when a crop of fruit is being borne.

Many experiments have been carried out with organic and chemical manures and results have frequently been disappointing. In most tropical soils suited to coffee it seems that the tree finds most of what it wants for a considerable period of years, and since there has been little response to manuring, planters have considered that manuring coffee is not economic or worth while. This may indeed be the case if mulching is adopted, for the mulch as it decays may largely make up for the materials taken from the soil by each successive crop. If mulching is not practised and the soil is bare of shade then it must become deficient in nutrients in time, and probably at an accumulative and faster rate. That is to say that manures may later be a vital necessity and have a definite influence on crop yields provided they are then supplied in sufficient quantity.

Herein lies a snag. The loss year by year is insignificant on a fertile soil. The effects of erosion on water conservation are most noticeable and they

mask the effects of soil infertility. Manures are supplied in quantities which can be afforded and those quantities may not be enough. Because coffee shows little response to the manuring that has been attempted, is no argument in favour of using no manures at all.

The author has visited many poorly cultivated patches of native-grown Arabian coffee. He remembers one occasion when all the coffee trees of one patch were exceptionally poor except one, and that one stood at the back of the owner's hut in the midst of his refuse tip. It was entirely healthy and bore an exceptional crop of coffee. What was the lesson to be derived from this? If every tree had been given the same amount of refuse they would have been similarly prosperous, but if the amount of refuse available had been spread throughout the planting then it might have proved insufficient. If one manufactured the same amount of compost and paid labour to make and spread it, then it might not prove economic to use the same amount.

There would seem to be a balanced economy in the need of the tree, i.e., between too much and too little. Visually the trees may be much improved in health because of extra leafage and growth, whereas in fact the yields may drop if too much nutrient be provided.

Then there is sometimes a delayed action. Adding potash to the soil appears to have a delayed effect. Coffee trees require a lot of potash according to analysis, and yet when potash is applied there is usually very little response for at least two seasons. Afterwards increased yields may become significant. No general rule can be laid down, because all soils and localities differ, and because everything depends on the environment.

The lack of response to manuring must be due to one of the following: (*a*) The soil has been sufficiently fertile in the beginning, and at the point when too much fertility depresses yields rather than increases them. Several authorities have remarked on the visual health of the trees on manured plots. (*b*) The manures have been given at the wrong times, i.e., when the roots were not active, or when the heavy rains exerted their leaching effects. (*c*) The quantity of manures or chemicals given has been insufficient. (*d*) There have been interfering and competitive factors such as interplanted shade trees and cover crops. (*e*) There has been the masking feature of insufficient moisture supplies or deficits in the subsoil common at least in parts of East Africa.

Some authorities have recorded excellent responses to manures, especially to potash and nitrogen, but rarely to phosphates. Beckley states[3] that there is an ample supply of potash in Kenya soils, yet there is a marked response to potash manuring. Continual applications of ammonium sulphate will alter the environment by creating high acidity values in the soil.

Notwithstanding all this preamble, we know by analysis what constituents are found in the coffee berry and the coffee bean at different stages of their growth, and in the leaves also. We can compute the amounts of nutrients which are being taken from the soil and their approximate ratio.

Anstead and Pittock have supplied us with analysis figures of berries throughout a crop season, and of cured beans.[2]

ANALYSIS OF FRESH COFFEE BERRIES FROM JULY TO JANUARY

	July	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*
Moisture % ...	87·13	84·45	80·75	71·54	66·06	65·77	66·62
Organic matter ...	11·96	14·67	18·16	26·93	32·05	32·48	31·58
Silica	0·04	0·01	0·03	0·02	0·02	0·04	0·05
Phosphoric acid ...	0·08	0·07	0·09	0·16	0·15	0·12	0·12
Potash	0·37	0·43	0·49	0·77	0·93	0·88	0·96
Lime	0·04	0·02	0·02	0·02	C·04	0·02	0·02
Other chemicals ...	0·38	0·35	0·44	0·56	0·75	0·69	0·65

ANALYSIS OF ASH OF COFFEE BERRIES FROM JULY TO JANUARY

	July	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*
Silica %	4·48	1·48	2·84	1·23	1·11	2·47	3·03
Phosphoric acid ...	8·48	8·04	8 20	8·40	7·87	6·56	6·86
Potash	40·31	48·38	45·78	50·30	49·40	50·10	33·19
Lime	4·27	2·04	1·89	1·17	1·89	1·23	1·14
Other minerals ...	42·46	40·06	41·29	38·80	39·73	34·64	35·81

ANALYSIS OF COFFEE

	Ripe Fruit	*Cured beans*	*Ash of Coffee beans*
Moisture %	47·09	7·97	—
Organic matter	50·37	84·67	—
Nitrogen	0·876	2·285	—
Potash	1·11	2·025	62·47
Lime	0·18	0·16	6·29
Phosphoric Acid	0·17	0·37	13·29
Silica	0·08	—	0·54
Soda	0·05	·095	1·64
Magnesia	0·12	0·36	9·67
Oxide of Iron	0·06	0·055	0·65

Potash is a dominant factor in the mineral constituents of the coffee bean. The crop requires potash and nitrogen at all times, and phosphoric acid, it seems, chiefly at the beginning of the season.

Several authorities have sampled the contents of leaves at different seasons and in respect to the yield of the berries. Clements[5] suggested that his results indicated that the principal influences of yield upon concurrent growth were brought about by a withdrawal of potassium from the vegetative parts of the plant. The growth of laterals may be curtailed by a potassium deficiency caused by the supply of potassium to the fruit.

Roelofsen and Coolhaas[26] state that the decrease in the amounts of phosphorus, nitrogen and potash in full-grown leaves as the season advances is probably on account of the ageing, but that the minimum amount of potash in the leaves coincides with the ripening time of the coffee berries. They observed that of fruit-bearing branches, the berry alone may contain 75 per cent of the total amount of potassium present in the branch, 65 per cent of the phosphoric acid and the nitrogen together, 60 per cent of the dry weight and the carbon, 40 per cent of the magnesium and the manganese, and 30 per cent of the iron and calcium.

According to Schweizer[28] the phosphates, nitrogen and potash reach their peak in the leaves of crop-bearing trees when they are fully grown and expanded, after which the phosphates and nitrogen slowly decrease until leaf fall, but the potash tends to migrate from the beans to the leaves. With trees that are not in bearing, all three nutrients decrease shortly before leaf fall.

He states that a normal crop withdraws none of the ash constituents or nitrogen from the leaf but only from the bark and wood of the branches, whereas, when a bumper crop is borne, all parts of the tree must mobilize its reserves of nutrients. Phosphates may decrease up to 60 per cent of the original amount within the plant, starch disappears entirely and the total sugars may decrease to 4 per cent of the total.

In conclusion he remarks that the consumption of carbohydrates while the berry is turning red is enormous. When the carbohydrates of the branches, stem, and roots, have all disappeared, then the beginning of die-back of the branches is the beginning of the decay of the whole tree.

Overbearing is, of course, a symptom that something in the environment is wrong. If the tree becomes exhausted and begins to die-back then the environment is doubly at fault, albeit there are very few environments where coffee is grown that are not at fault in one way or another.

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Chapter V

SHADE AND WIND BREAKS

Reasons for Controversy in regard to the Provision of Shade

To most coffee planters the question of shade is a very vexed problem, and one which is discussed whenever coffee men foregather. It is indeed a matter for theorizing and hard thinking, because most of the advice that can be given has been gained by experience and observation, rather than from research. Even when research has given results, these may only be applied strictly to the immediate locality where the investigations were made. There are many such questions as the following to answer. Does coffee in any one locality require overhead shade at all, and if so, how much? What species of shade tree will grow best on a particular plantation and type of soil? Will it be in harmony with the coffee and not compete too seriously for the available moisture and nutrients in the soil? At what distance apart should the shade trees be planted, and how should they be reared and trained into trees? Will the planting of a particular species of tree prosper the pests and diseases of coffee, and can it serve a dual purpose by supplying timber, firewood or some other useful commodity? A most important question perhaps, is whether soil shade is more important than overhead shade, but this is related to the first question.

No two coffee-producing countries are alike in the climatic and soil conditions they offer. No two coffee plantations can be considered alike unless they lie adjacent on a very uniform soil having the same slope and aspect, and seldom is a single coffee plantation alike in its separate parts, if it covers several hundred acres of undulating country. For these reasons, few of the trials and demonstrations of a central experiment station can be applied with absolute certainty to surrounding plantations in the same region unless extension work has been considerable.

To give point to these arguments it might be apposite to quote one region, to wit Kilimanjaro Mountain in Tanganyika, where the cloud masses are intercepted, and the moisture is deposited, chiefly on the higher south-eastern slopes. The shade tree in use is the *Grevillea robusta* A. Cunn., and on the middle slopes at an altitude of 4,000 feet where the rainfall averages 50–60 in. the tree has served coffee fairly well, provided it has not been planted too closely spaced. Together with a rich volcanic loam of good structure, and a fair rainfall, there is generally enough moisture retained in the soil for both the coffee and the shade trees during the dry months of the year. Both then appear to be in harmony. Some overhead shade would appear to be necessary to regulate the flowering and to reduce the possible incidence of thrips in that particular neighbourhood.

Where coffee is grown at levels lower than 4,000 feet on Kilimanjaro, the rainfall is much less, and the dry seasons are hotter and longer. Overhead shade would appear to be necessary at a closer spacing, but there is insufficient moisture to carry both the coffee and the *Grevillea robusta* through the dry season without harm to the former crop. The *Grevillea* is too greedy for

moisture, especially when the trees grow to maturity, and if coffee must be grown at low altitudes in an area unsuited for its healthy growth, then it would be wiser to seek some other shade tree that does not compete for the moisture supply to the same extent.

Conversely, at altitudes of 5,000 feet and more, in this self-same region, the soil has a better structure and the rainfall is much heavier, in the neighbourhood of 75–80 in. per annum. Temperatures are colder, indeed, quite cold at night, and the showers are more evenly distributed throughout the year. There is also a great deal of mist, especially when the clouds are low, with a consequent condensation of moisture and diminished sunshine. Under such conditions Arabian coffee finds its ideal home, and it thrives without shade.[2] If the soil is kept covered with litter, the individual trees respond with better growth.

Here, then, on Kilimanjaro, the environment and shade differ widely at the low, middle and higher altitudes, where the kind and quantity of shade requires careful consideration and different treatment, though conditions between each of the three altitudes merge and alter gradually as the mountain is climbed, making it very difficult to decide where one treatment should end and another begin.

Many planters will have noticed that when some of the indigenous trees are left standing among coffee, they are not harmful at all, so that the coffee bushes grow, if anything, more healthily within their root-range than at a distance. On the other hand the reverse is often true, for some species of forest trees have a malignant effect on coffee, causing the bushes to grow spindly and unhealthy, with chlorotic leaves and wilting growths. In the absence of proof that the roots have some anti-biotic action detrimental to the coffee, one must presume that they compete with the coffee for moisture and nutrients, either by drying out the subsoil, or by their extensive and greedy root systems.

The Use of Banana Plants

Bananas appear to grow in harmony with coffee, especially when the coffee is grown on a multiple-stem system, so that the stems can bend away towards the light. The uneven shade is one of the disadvantages, and also the fact that violent storms may blow down the heavy pseudostems and thus damage the coffee. The fact that bananas get out of line because of their habit of ratooning from creeping rhizomes has often been mentioned, but this can be controlled up to a point by the choice of well-placed suckers and the destruction of the remainder. In any case, only two, or at most three banana stems, should be permitted to grow at any one time from each stool.

One might say that bananas are useful as temporary shade in some circumstances, and the litter they give for mulching the soil is beneficial. After about six to ten years the banana stools weaken considerably unless they are kept heavily manured, and by this time the coffee has matured and is demanding most of the space. It is then very difficult to establish many of the best permanent shade trees, and it is only possible to plant large pole-cuttings of species of *Ficus* or *Erythrina*, which do not always thrive in all localities. The planting of robusta coffee has been encouraged in native banana plantations, where it has thrived and given a catch crop together with a food crop, but in such situations the food supply is of first importance and the coffee is supposed to be a secondary consideration. It would not be wise for commercial

interests to use the banana for shade, especially among Arabian coffee.

In spite of the big leaf-spread and the moisture-loving nature of a banana clump, it is surprising to find how invariably the soil is moist adjacent to the roots. It may be this, and the mulch available, which allows a coffee plant to grow happily close to a banana plant; there is sympathy rather than antipathy between the two.

Use of Indigenous Trees

The author wishes to emphasize the question of harmony, for he is convinced that plants in the wild state grow in harmony with their neighbours, and that this goes a long way to explain all the associations of plants, whether they be annuals, herbaceous perennials or forest trees. It may not just be a question of how much light and air there is, or of the root ranges of neighbouring plants and the type of soil, or of competition for the available moisture and nutrients which decide whether one species of plant may grow happily close to another. There is something more going on beneath the soil where the roots antagonize or bear with each other as they endeavour to intermingle. Seeds of parasites germinate when they are in contact with the roots of their host, and it has been shown, in some cases, that substances of an anti-biotic nature are exuded from the roots of one group of plants which may tend to inhibit or depress the root growth of others. One might theorize and say that plants using the same offensive substances would perhaps of necessity grow in harmony—provided other influences were overcome by a natural give-and-take—having the ability to adapt themselves and to survive the struggle to share the necessities of life.

Whether this is so or not, Arabian coffee in particular, and robusta coffee to a degree, appear sensitive to the presence of other trees and inter-planted crops. They either harmonize and appear to take no notice of their neighbours, or they suffer in proximity. Maize, for instance, is a dangerous crop to inter-sow in young coffee, for though the sowing may be thin and the soil be kept moist, the leaves of the coffee will not retain their full health and the young branches will tend to grow spindly. For this and other reasons it may be unwise to permit a mixed weed growth even in the wet season, and even though it may be kept cut short. It is far better to shade and mulch the soil with litter and prevent erosion by contour planting and protective works.

It is, therefore, most important to choose a shade tree with which coffee will grow in complete harmony. As one might suppose, many a leguminous tree will serve this purpose, but not all of them are suitable. We must not forget that root-range and greed will also exert their influences, and that trees of other Orders and Families will often give as good service. The author has noticed how much better Arabian coffee seems to prosper when it is close-planted beneath the shade of the sausage tree, *Kigelia aethiopica* Decne., a member of the *Bignoniaceae*, wherever a tree has been left growing in the middle of a coffee garden in low-altitude country in Africa. Coffee should not be planted under natural shade in forest clearings unless the trees that are allowed to remain have been tested and found to grow in harmony.

Thomas[11] records that in Uganda, the trees *Antiaris africana* Engl., *Canarium schweinfurthii* Engl., and *Maesopis eminii* Engl., appear to have a beneficial effect on coffee, whereas *Piptadenia buchanii* Baker and *Albizia zygia* (DC) Macbride, are definitely harmful, although the light foliage promises an excellent shade.

He goes on to state that species of *Ficus* are commonly planted in African gardens in Uganda to provide shade for robusta coffee, and though these are not ideal, they do not appear to do the coffee harm and they give some return to the native landholder by reason of the cloth which is manufactured from the bark. Generally speaking, *Ficus* species are very greedy for soil moisture and nutrients, and there may be several coffee-growing regions where they would be harmful.

In one locality a tree might be found ideal because the soil retains moisture, whereas in a neighbouring place the same tree might be harmful, or might not grow successfully itself and give the required amount of shade because the soil was one that dried up too quickly. Efforts in the past have mainly been aimed at obtaining ideal conditions for the coffee plant, but if the coffee must be shaded, then similar conditions must be found for the shade trees as well. In other words a shade tree must be selected which will succeed in the environment selected for the coffee, and which, under these conditions, will have a beneficial effect on the coffee.

The same tree might not flourish in another situation, and even if it did, it might be harmful to coffee, so the matter is somewhat complicated. It is this which causes so much controversy, whenever coffee shade is mentioned among planters.

Use of Fruit or other Economic Trees

When Arabian coffee planting began in Uganda, the intention was to use coffee as a catchcrop between Hevea rubber. Planters were uncertain which would pay best, and as both crops grew older neither was usually sacrificed until it was too late. By this time the rubber had overshaded the coffee and given far too much root competition, so that the older planted coffee was no longer of economic use at a time when the price of rubber fell to zero.

It is fatal to be uncertain in this manner. Coffee will not often lend itself like soft fruit does, in a temperate orchard, to serving as an undercrop among 'top-fruit'. When trees are planted as shade, then the shade trees must suffer and be lopped if they grow too strongly and produce too much shade. It is not possible to lop rubber trees without spoiling them.

In Central American countries in particular, and in many other parts of the world, it is the practice of the peasant people who grow coffee trees for profit to interplant them in their gardens among a mixture of fruit trees, using the fruit trees as shade. It is not a wise practice, for several of the pests that attack the fruit trees become disastrous parasites on the coffee; e.g., mealy bugs. Neither will the owner reduce his shade if it means lopping an orange tree, a guava or a bread-fruit tree.

It is possible, as has been mentioned, to plant coffee among bananas, but it is not wise because of the uneven and temporary nature of the shade they give.

The Effects of Shade

What effect does shade have on coffee? Firstly it is generally believed that robusta coffee requires more shade than Arabian coffee. Whereas Arabian coffee may find itself in situations where shade is unnecessary, robusta coffee seldom does. It grows naturally in a fairly dense forest, and it is not found wild in the open. This means that robusta coffee is likely to yield fairly well under a shade which would be too dense for Arabian coffee. Arabian coffee

is said to grow in forest glades and along river banks in its Abyssinian home.

Shade breaks the intensity of the light, and should reduce this to the amount required to give steady economic crops. At high altitudes, and in some special locations, the frequent clouds and persisting mists may give the same effect. Shade is reduced by planting the shade trees farther apart, or by lopping their branches, remembering always that the afternoon is the hottest time of the day when the sun begins to sink towards the west. Lines of trees planted north and south will throw shadows across the land.

Readers should refer to Chapter IV on the environmental requirements, and the physiology of coffee. It is shown that photosynthesis ceases in strong sunlight, that the stomata close, and hence the production of starch and thereafter of sugar must largely be interrupted in all the leaves except those that are shaded by the tree itself. This must seriously affect the growing parts. It is the nature of plants to sacrifice themselves for their progeny, so that the growing parts, the leaves, the roots and the whole structure of the tree will suffer in favour of the swelling fruit, if manufactured nutrients are in short supply. This leads to leaf yellowing and leaf fall, followed by die-back. Shade in varying degrees is therefore indicated for coffee in all but the very few localities where the light intensity is not enough to disturb the manufacture of carbohydrates.

Saunders and Wakefield[10] state correctly that in the tropics the light intensity is high over long periods and carbohydrate assimilation is rapid, while the absorption of inorganic salts from the soil is depressed. This, they say, results in a wide C : N ratio causing an abnormally heavy production of fruiting buds which the tree is unable to bring to healthy maturity, since there is then a very heavy drain on the stored reserves of food in the tree, often to the extent that the food materials are insufficient to ripen up the crop and also to allow of vegetative growth. In the following year the consequence of this small vegetative growth is a low carbohydrate content and therefore a narrow C : N ratio; a condition which, as has been shown, they state, does not allow of fruit-bud formation.

They appear to be wrong, however, when they state that the reduction of light intensity depresses the production of carbohydrates. It does if the shade is too dense. A light shade reduces the light intensity to the point where the leaf stomata remain open all day, so that photosynthesis can proceed and hence the production of carbohydrates is increased.[5]

Wherever shade is used it affects flowering and tends to produce even crops in successive seasons. Whenever Arabian coffee is grown where temperatures are too high and rainfall is too low the trees overbear their strength, and thus bear a bumper crop one year followed by exhaustion and at least two years of low yields. Shade has the effect of reducing the number of flowers produced to within the capability of the trees to bear the crop without exhaustion. Again the reader is referred to Chapter IV and the paragraphs concerning the initiation of flower buds.

Shade helps to keep the air moderately still, it protects the coffee bushes from hail, and it reduces the temperature of the air and of the soil; it reduces the rate of transpiration and therefore of evaporation both from the leaves and the soil. Piché tubes used at Kampala in Uganda gave lower readings in shaded coffee plots than in those that were unshaded, the difference being greater in the dry season.[11]

Shade depresses weed growth, especially that of some of the more noxious

weeds, and this is important where labour is scarce, or where for some other reason, such as the growing of coffee by irresponsible and illiterate peasants, vigorous action to control weeds is not to be expected. When crops are borne more regularly, controlled by the amount of shade permitted, then all the subsequent tasks of harvesting and preparation run smoothly, and a higher percentage of good quality coffee may be obtained. Overbearing, and bumper crops, with the consequent rush to pick the crop before it gets over-ripe, place too great a strain on the pulping, fermenting and drying operations, with the result that a low quality prevails. Coffee is placed too thickly on drying trays so that it dries too slowly, or part of the crop is stored in bulk before it is fully dry to give room for successive pickings. The coffee then has musty flavours. During the following seasons the crops are so small that the machinery and equipment is not used to its full extent, and the working of it is hardly economical. Good management will strive towards regular crops and just the right amount of equipment to deal with them, and a proper amount of shade will aid this aim, and obviate the practice and cost of stripping and sacrificing immature berries when a crop is considered to be too large.

Comparative trials in Uganda[9] over a period of twelve seasons concerning treatments comprising shade, and no shade, clean weeding, temporary cover crop, full mulch and alternate row mulching, were sadly interfered with throughout the years by the recorded fact that all the plots had been under heavy weed cover for long periods owing to a shortage of labour. The yields of the unshaded plots were often heavier than those which were shaded but the shaded coffee was obviously more healthy. Organic manures appeared to have a greater effect on the shaded plots, which would appear to indicate that this counteracted the withdrawal of nutrients by the shade trees and permitted the shade to exert its full influence. It must be remembered that the rainfall in Uganda is short for coffee, and hence any competition for the moisture supply exerted by shade tree roots or cover crops has a primary importance and effect. The *Gliricidia* shade used in the beginning was not of the best kind, and it had to be replaced by *Ficus* sp. which again affected the records.

THE PROTECTION OF COFFEE FROM COLD NIGHT TEMPERATURES

Thomas[11] agrees that Arabian coffee near the equator in Uganda grows quite well at altitudes between 5,000 and 6,000 feet without shade, but he goes on to state that when coffee is grown at the higher altitudes it sometimes requires shade for another reason, i.e., not to keep the coffee cool by day, but to keep it warmer at night. He mentions the 'hot and cold' disease, the symptoms of which are a very slow growth and a compact habit of branching, also a yellowing and scorching of the leaves, all of which are largely caused by excessive cold, though an excessive acidity of the soil at these altitudes may be a contributing factor. Overhead shade will often prevent this trouble. He records how T. W. Kirkpatrick had shown that the temperature of the air surrounding shaded coffee on clear nights may be from 4 to 5° C. higher than among unshaded bushes.

Cold kabatic streams of air flowing down the slopes of Kilimanjaro from the ice-cap of Kibo peak would doubtless preclude the cultivation of coffee higher than 6,000 feet. In the Southern Province of Tanganyika between 8° and 10° south from the equator, at an altitude of round about 4,000 feet, light frosts occur in valley bottoms during the colder season of the year, and

here the author has seen the same symptoms of slow and stunted growth on account of the cold air. Even on the valley slopes coffee seedlings were taking one and two years to grow as tall as nine inches. Cold air streams flowing downhill can sometimes be diverted or mitigated by thick barriers of trees planted along the upper boundary of a piece of land, and, of course, cold winds may be hindered by windbreaks of stout trees.

Shade Trees and their Qualities

Having fulfilled the qualities which have been mentioned, the perfect shade tree should be one that has a long life. Its wood should not be brittle, leading to breakages of heavy branches during high winds. Moreover the branches should have a spreading habit and bear feathery leaves which will not cast too dense a shade. It should be possible to train the tree with a clean trunk so that the branches may spread at a height of several feet above the coffee growing underneath, and it should be one which will bear considerable lopping and pruning without submitting to wound diseases. It should be a tree which is not a host plant for any of the serious pests and diseases of coffee. All this having been said, can one wonder at the difficulties which confront a planter in his choice? The ideal is rarely possible, so one must put up with the next best thing, and it is not surprising that the list of commonly used shade trees in the world is not of great length.

Grevillea robusta A. Cunn., known as the silky oak, belongs to the family *Proteaceae*. It has an upright medium-sized growth of a pyramidal shape, and since the branches do not spread to any great extent, the intervening spaces between the trees are not always shaded from the mid-day sun in equatorial regions. Moreover, the shade underneath the trees is often too dense. The timber is tough and durable, and for this reason the branches are hard to lop. There is a fair and continual leaf fall which provides a thin mulch; but the tree is a gross feeder, and greedy for moisture, so that it is not advisable to plant it among coffee at low altitudes where the rainfall is low and unevenly spread. The tree is not choosy in regard to its environment, and it will grow successfully in most countries and localities where coffee is grown. It throws long shadows in the late afternoon, and hence it is most useful for planting as avenues along estate roads, or as a wind-break tree along the boundaries of plantations. Planted in lines among other more brittle trees it will provide a stiffening or protection from strong winds, and thus prevent breakages.

Perkins[6] has noted the effects *Grevillea* trees seem to have on the early flowering of Arabian coffee at an altitude of about 6,800 feet on the eastern slope of Mount Elgon, where the soil is a dark forest loam and the rainfall averages 52 inches per annum. He found that the coffee shaded by the *Grevillea* gave a prolific and early flowering, especially the trees interplanted in the *Grevillea* rows, and the next coffee row to the west of each shade row. This tendency towards early and profuse flowering diminished as the shade effect grew less, until, at 30 to 35 feet distant from the *Grevillea* trees, early flowering was not noticeable. The *Grevillea* trees were 35 to 40 feet tall in rows running north and south spaced 135 feet apart, the trees planted 36 feet apart in the rows.

On account of this effect, Perkins suggests that the rows of *Grevillea* would be best spaced from 60–70 feet apart to obtain the same effect on flowering throughout a plantation. He recorded, however, that the earliest flowering

took place before the previous crop was off the trees, and that the first important flowering occurred immediately following the completion of harvest.

In the author's opinion this is not a favourable sign since the coffee would not be given sufficient rest. The rainfall of 52 inches is short, and the trees were probably feeling the root competition from the *Grevillea*. Early flowering might well be an indication of a struggle for survival, leading to exhaustion, rather than one of health.

The rain tree or saman, known as *Pithecellobium saman* Benth., grows to a great size in hot and moist regions at low elevations. It grows slowly at higher altitudes where coffee is more at home, and, like the silky oak, it has the advantage that it is long-lived. Its timber is also durable and useful. The branches bear a feathery foliage, and they spread upwards and outwards to form an arch with neighbouring trees, even though they may be planted forty feet apart. It is a tree which seems to grow in harmony with coffee in most situations, but its shade is likely to become too dense and require constant pruning to keep it under control. It is not a shade tree that one would advise for Arabian coffee in the cooler regions, but it might often be of use for robusta coffee where both temperatures and humidity should be higher if the coffee is to grow well. As with the silky oak a spacing of fifty feet apart is not too wide.

Next in common use, perhaps, are species of *Erythrina*. Several of these are known as the 'Madre-de-Cacao' in South America. First there is the Dadap, the popular name given to *Erythrina lithosperma* Bl., a moderate-sized tree without spines, and also to *E. indica* Lam. Both make rapid growth where they happen to prosper. If they grow well they grow luxuriantly, and provide a great quantity of green foliage for mulching purposes. According to Macmillan[3] one ton of loppings of *E. lithosperma* contains 61·50 lb. nitrogen, 57·38 lb. potash, 15 lb. calcium, and 13·68 lb. phosphoric acid. The trees usually thrive under climatic conditions that are humid, moist and not too cold. The leaves are large and trifoliate, the branches inclined to be heavy as they grow larger, and the trees need spacing at 30 × 30 feet, up to 40 × 40 feet according to how successfully they grow.

In the West Indies *Erythrina umbrosa* HBK., the Mortel, and *E. velutina* Willd., are popular shade trees. Both have large trifoliate leaves, but those of the latter are tomentose. They form moderate-sized trees when they are flourishing, and usually require planting about thirty feet apart.

Coffee always appears healthier under the leaf spread of *Erythrina* sp., provided the shade trees grow well and retain their leaves during the hottest season of the year. Unfortunately they drop their leaves and tend to become deciduous in some localities, wherever the soil dries out too quickly and the dry season is very marked. In East Africa, for instance, they cannot be relied upon to make good growth, except in one or two small regions, partly because boring grubs invade the young branches and kill back most of the twigs. The younger growth is very sappy and for this reason it is easily lopped.

Other species of *Erythrina* have been tried, among which is *E. micropteryx* Popp. ex Walp., introduced into Uganda in 1913. This formed large spreading trees which proved useful as coffee shade in one locality, to wit Kakumiro, but in other parts it was killed back by the stem-boring caterpillars.[11] A number of species of *Erythrina* are indigenous in Africa. Four grow into tall trees in countries of the West Coast.

By courtesy of the Royal Institute for the Tropics, Amsterdam

An old plantation of Arabian coffee under the shade of *Erythrina* sp., East Java

PLATE XIV

Photo by author

(*a*) Young Arabian coffee with *Gliricidia* shade, North Mara, Tanganyika Territory

(*b*) Young robusta coffee with high shade and soil-cover shade of the Lamtoro *Leucaena glauca*, E. Java

By courtesy of the Royal Institute for the Tropics, Amsterdam

PLATE XV

By courtesy of the Royal Institute for the Tropics, Amsterdam

(*a*) Two-year-old grafted robusta coffee under the Lamtoro *Leucaena glauca* shade, E. Java

(*b*) A plot of Arabian coffee belonging to a peasant in North Mara, Tanganyika Territory. Note wide planting, lack of ground cover, no shade, and wind damage. Despite faults, the trees would have been promising if shelter had been given

Photo by author

PLATE XVI

To sum up, the species of *Erythrina* form most useful shade trees for coffee wherever their growth is satisfactory, but it would appear advisable to give them stiffening by planting occasional lines of a tree such as *Grevillea* to break the force of wind storms. Most of the *Erythrina* species can be propagated easily by planting thick, pole-like cuttings eight feet long, and they root so readily and grow so quickly that it is unnecessary to propagate from seed if there is sufficient material available for planting t the proper season.

The next important shade trees are species of *Albizia*, and there are three commonly used, the first *A. falcata* (L.) Backer [Syn. *A.* moluccana Miq.], being, perhaps, the best known. This tree is a fast grower, and its spreading branches and feathery leaves form a very fine shade for coffee, since coffee is not harmed and is actually benefited by growing in association with a tree which creates in course of time a fine litter of leaves upon the ground. The timber is soft, so the branches are not too hard to lop, and the soft timber of old trees is useful for box-making. Unfortunately it has two disadvantages. Firstly the timber is very brittle, so that heavy branches are likely to split and break off during severe wind storms, though this might be prevented by planting it in blocks sheltered by avenues of *Grevillea robusta* along dividing roads. Secondly the tree may be short-lived, since many have died of root diseases within ten years in Uganda.[11] The trees should be spaced at least forty feet apart.

Albizia chinensis (Osbeck) Merr. [Syn. *A. marginata* (Lam.) Benth.; *A. stipulata* (Roxb.) Boivin] has prominent stipules, and these and the young leaves are both tinged with pink. This tree has been found the best shade of all in East Africa, for it has a fast growth, it is grown easily from seed, and it makes a fine spreading growth of finely divided leaves within a few years. The wood is medium soft but not so brittle. In the beginning the young tree has the annoying habit of growing at an angle as though it needed staking to hold it upright, and staking, of course, would help it to make a straight trunk. After about two years, however, the stem straightens itself, and with appropriate pruning a clean bole can be obtained. The foliage is so light that very little lopping is required with a spacing of forty to fifty feet apart, and though it has been reported that the tree is short-lived in hot regions, it is still vigorous at an age of twenty years at the higher altitudes and cooler temperatures of Kenya. The tree may be propagated by taking large cuttings, because branches about 6 feet long and 3–4 inches thick will root easily, though a tree is of better shape when it is grown from seed.

Albizia lebbeck (L.) Benth., is used successfully in India, Java and the West Indies, and grows into a useful shade tree in a suitable environment. In East Africa it makes a slow and unsatisfactory growth, for the tree throws its whole energy into producing seed pods at the expense of growth. It does not seem to benefit coffee so well, and in the experience of the author it is not a shade tree that should be planted among coffee if the other trees already listed would make a satisfactory growth. Before choosing a shade tree for a new plantation it would be wise to search the countryside in an effort to find mature specimens of most of the common shade trees so that their growth may be observed. In most of the older coffee-growing regions it will be found that all the shade trees have been tried at some time or other, and specimens will be seen growing at mission stations, in old estates, or in botanical gardens.

Albizia adianthifolia (Schumach.) W. F. Wight [Syn. *A. fastigiata* (E. May.) Oliv.] has been tried for crops of coffee, tea or cocoa, and several other species

may be found indigenous in local forests. None has been tried to any great extent or proved satisfactory.*

The Madera, *Gliricidia sepium* (Jacq.) Steud., formerly known as *G. maculata* HBK., has been used as a shade tree, e.g., in Nicaragua and other Latin American states. It is a smallish tree and awkward to handle, because of the long spray-like branches which grow in such profusion that it is not easy to obtain a long clean bole that will carry its head above the coffee. Coffee undoubtedly grows in harmony with the tree and benefits from a mulching of the loppings. The young branches are soft and easy to cut, but the crown does not spread very well. It grows very fast and is readily propagated from branch cuttings planted *in situ*, or from seed. To form a bole, one of the long upright growths must be topped at about eight feet tall, and all other growths pruned away except those which are to form the head. The trees should be planted a little more than twenty feet apart, and later thinned by cutting out alternate lines. A serious disadvantage is that the tree has been found a host for mealy bugs which attack coffee.

There are many other trees used in various countries as shade for coffee, though these are not so well known. There is the small-leaved bark-cloth fig, i.e., *Ficus* sp. used among robusta coffee in Uganda. In the early days, long pole-like cuttings of these trees were planted along roadsides to act as telegraph poles, because they rooted readily and were then not attacked by white ants. They are easy to propagate from large cuttings, so that a tall clean bole is at once available, sprouting out at the top to form a spreading canopy. These trees might not do well in other countries, nor at high altitudes, and the roots are greedy for moisture in soils that are on the light side. An indigenous tree *Cordia holstii* Gürke, has been used in Kenya[4] but the author would not advise planting it because he has seen its effect on coffee at the lower altitudes of Kilimanjaro wherever indigenous trees were left standing. *Adenanthera pavonina* L., has been used in some countries, but the tree often makes a poor growth. The same can be said for *Leucaena glauca* (L.) Benth., which grows in a slender fashion and produces such an abundance of seed pods in Uganda, that it seldom succeeds in growing into a tree. For this reason it is sometimes used as a soil cover to prevent erosion, or as a green manure, although the root stocks become so woody with frequent cutting that they are difficult to eradicate.

Leucaena glauca, known as the 'Lamtoro', is, however, used a great deal in East Java. Rows of it are sown between the coffee and kept sickled at a low level to produce soil cover. At proper spacings stems are allowed to grow to produce high shade, and though the stems are somewhat slender and awkward in shape in the beginning, they ultimately develop an efficient overhead shade.

It is recorded by Van der Veen[12] that the *Leucaena glauca* is able to produce nitrogen in the soil from its root-nodules, whereas *Desmodium adscendens* DC. [Syn. *D. ovalifolium* Guill. et Perr.] and *Indigofera spicata* Forsk. [Syn. *I. hendecaphylla* Jacq. *I. endecaphylla* Jacq.] do not release the same amount while the plants are young. He states that coffee grown with these other cover crops suffer badly from root competition, and recover only after a period of heavy mulching.

**Albizia gummifera* (Gmelin) C. A. Smith, which has been confused with *A. falcata*, *A. chinensis*, and *A. adianthifolia*, is a different species. All may be grown as shade trees. The taxonomy of these species was worked out by Brenan in Kew Bull. 1952, 507-537 (1953), in a paper entitled 'The *Albizia gummifera* complex'.

In Java, a small tree with fine foliage named *Derris microphylla* (Miq.) Jacks., has been used, and the Spanish Ash, *Inga laurina* Willd., has been planted to shade *Cacao* in the West Indies. Several other species of *Inga* are used in Mexico and other Central American countries. They often appear haphazard but are sometimes planted, and *Inga vera* Willd., is stated to be a favourite. *Myroxylon balsamum* (L.) Harms., [Syn. *M. toluiferum* A. Rich.,] *Pongamia glabra* Vent., and *Tecoma leucoxylon* Mart. ex DC. are also listed as shade trees.[3]

Shade trees should be planted out in the field either a season in advance of coffee, or at the same time. It is well-nigh impossible to establish coffee among mature shade trees, and conversely, it is difficult to establish young shade trees among old coffee. The best way would be to use pole cuttings of trees that can be propagated in this manner, though these do not always make satisfactory growth.

If the seeds of the shade tree are large and fresh, an attempt may be made to sow them at stake in the field, placing three or four seeds at each stake, and thinning the seedlings to one plant at each spacing when they have grown beyond the hazards presented by mole crickets and cut-worms. There will, of course, be vacancies to fill, so that a reserve supply of plants should be raised in a nursery for planting out before the season ends. For nursery treatments, and methods of planting, see the chapters on propagation and planting.

Temporary Shade

When coffee is first planted in the field, the young plants are usually shaded for a few days with a few short pieces of palm leaf or other suitable vegetation, pressed into the soil and arranged conically in the form of small awnings over the plants. Quite a number of planters then believe in planting a thin sowing of a tall leguminous crop such as pigeon peas, or species of *Crotalaria*, or *Sesbania*, to give a temporary shade until the permanent shade becomes effective.

Young coffee plants should be hardened off to the sun before they are planted in the field, and while they are still in the nursery. In the experience of the author, sunshine does little or no damage to young coffee when the roots have taken hold, until the bushes bear their first crop of fruit. Since it takes three or four years from planting for Arabian coffee to start fruiting in the cooler climates where it is most at home, this should give ample time for a fast-growing permanent shade tree to give enough shade, especially if it has been planted, as it should have been, in the season before the coffee was planted out in the field. Given just that start, and spaced nowhere nearer to a coffee tree than eight to nine feet, the roots will not have grown far enough to interfere with the successful establishment of the coffee.

To be effective, a sowing of a temporary shade must be made near to the growing coffee plants. The subsequent growth of this vegetation is apt to rob the coffee plants of too much light and air, so that a spindly and sickly growth is encouraged. Moreover the roots of the shade plants must be very near the young coffee plants, and react upon them in competition for moisture and nutrients, as would tall-growing weeds. Though catch crops of a kind that will not be harmful, may be grown between the young coffee during the first two years, using only the middle part of the spacing between the rows, it would be far more effective and useful, in the author's opinion, if only the

soil were shaded in the vicinity of each coffee plant by a dressing of partly decomposed litter.

However, this is a matter for experience of the different localities where coffee is grown, and planters may try out the varying methods for themselves on different blocks of coffee, so that they may compare results and draw their own conclusions.

An indication of the effect which other growths have when they are intersown among coffee, is given in the results of an experiment at Lyamungu,[7] during the years 1934–36. It was desired to measure the amount of erosion and run-off from land planted with coffee at a spacing of nine feet apart, and subjected to different treatments. Plots were planted with 'Kent's' Arabian coffee in April 1934 on a uniform slope of 1 : 6, and the treatments were begun on the 21st March 1934 and were considered to be effective by the 1st February 1935.

These treatments were as follows:

Control plots were clean cultivated, and the others were sown to obtain (*a*) hedges of *Crotalaria* sp. across the slope thirty-two feet apart, (*b*) hedges of *Crotalaria* sp. together with a procumbent crop of *Dolichos hosei* Craib, (*c*) a mixed erect cover crop of *Crotalaria* sp. and *Canavalia ensiformis* DC.

The following table gives the percentage of moisture at a depth of 38 cm. in the soil, after two months' drought up to the 16th November 1936. It will be noted that the cover crops have decreased the amount of moisture in the soil by 2·0, 3·2, 3·3, and 4·0 per cent.

TREATMENTS AND SOIL MOISTURE PERCENTAGES

Sample	*Crotalaria hedge*	*Hedge and cover crop*	*Procumbent cover crop*	*Erect cover crop*	*Control bare soil*
I. ...	25·0	22·5	23·5	22·5	26·0
II. ...	24·5	22·0	23 5	22·0	28·0
III. ...	25·5	25·0	24·5	24·5	28·5
IV. ...	24·0	25·5	22·5	22·0	27·0
V. ...	24·5	22·5	23·0	22·5	24·0
Averages	24·7	23·5	23·4	22·7	26·7

When the coffee was planted, the young trees were all of the same age and size, and reared from the same parcel of seed. On the 21st December 1936, after a third month's drought, it was noticed that there was more leafage on the clean cultivated control plots than on plots given the other treatments, and the following counts of leaves were made:

Treatment	*Average number of leaves per coffee tree*
Crotalaria hedge and cover crop	194
Procumbent cover crop	163
Control clean cultivated	454

These results bear out the author's opinion that it is unwise to plant temporary shade or even catch crops among young coffee, when periods of dry weather are to be expected. Erosion must be prevented, of course, but this is best achieved by contour ridging and mulching with litter. It is evident that young coffee is likely to suffer more from the root competition of temporary shade crops, than it would from lack of shade.

Following the significance of the moisture losses in the soil shown by this experiment at Lyamungu, two other treatments were given in following years.[7] One of these was to draw the weeds on clean cultivated plots across the slope, thus tending to create contour banks in miniature which would hold up a certain amount of moisture and allow it to sink in. Other plots were given a mulch with banana litter, which, of course, shaded and cooled the soil and preserved the moisture percentage a great deal more. At four years old the coffee fruited, and the next table shows the results. The difference in yields on account of the increased moisture in the soil is astounding.

YIELD CALCULATED PER ACRE IN HUNDREDWEIGHTS

1 acre = 0·4047 hectares
1 cwt. = 50·848 kilogrammes

	Clean cultivated	*Weeds placed across slope*	*Crotalaria hedge*	*Hedge and cover crop*	*Procumbent cover crop*	*Erect cover crop*	*Banana mulch*
Fruit ...	32·25	59·69	40·41	41·17	43·31	40·24	68·09
Clean coffee	4·00	7·76	4·81	5·33	4·63	4·69	8·45

MIXED SHADE

Reverting to the question of permanent shade, and in an effort to create shade for the young coffee as quickly as possible without the deleterious effects of sowing a temporary shade crop, it might be advantageous to plant a mixed shade of fast-growing short-lived trees at a close spacing of about twenty feet, and a slower-growing long-lived and more valuable tree at forty feet apart. The faster-growing trees might be either a species of *Erythrina*, or the *Gliricidia*, or even the *Albizia falcata*, with *Albizia chinensis* used for the ultimate shade. All but the last would be cut out and destroyed as soon as it was considered advisable, using the twiggy leafage for mulching, and the thicker material for firewood. Stumps would have to be carefully eradicated and destroyed to avoid the incidence and spread of harmful fungoid diseases.

SHADE FOR LIBERIAN AND EXCELSA COFFEE

Liberian coffee is a forest tree or undergrowth in the hotter and steamy regions of the west coast, and it will not grow well where a heavy rainfall and suitable temperatures are not available. Given its correct environment in regard to other factors it should grow best under a light shade, and it is the sort of tree that will do well in a local botanical garden among mixed economic trees which shelter it from direct sunlight during the hottest part of the early afternoon.

Excelsa coffee is found growing in groups of tall trees in the semi-arid country of the west coast hinterland, and the best advice that could be given to those contemplating the planting of this species, would be to keep the soil shaded throughout its early life by mulching with litter. Overhead shade in the field should be unnecessary.

WIND BREAKS

Coffee is affected adversely by cold, dry winds, but a region subject to these need not necessarily be disregarded if shelter can be given. Shelter belts of trees should be thick and high, and composed of stout trees which will stand up to wind, interplanted with smaller growths to provide protection from ground level. Provided the trees planted grow in harmony with coffee there is no objection to the shelter belt being closely adjacent to the rows of planted coffee, though it is generally wise to leave an ample space where root competition may be fierce.

Many kinds of trees may be planted, such as species of *Eucalyptus*, Wattle, and *Casuarina*, if they are placed well beyond the root-range of the coffee, for such trees as these are definitely competitive and harmful when planted near coffee on account of the drying action they have on the soil. Wattles are useful at high elevations, and so are species of *Cupressus*, e.g., *C. macrocarpa* Hartw., and *Eucalyptus* sp. or *Grevillea robusta* at medium and lower altitudes. Some of the *Cassia* sp. also make good wind breaks and may be mixed to make a dense growth provided they are not near coffee. A thick shelter belt of trees will act as a firebreak in regions where surrounding grasslands may be fired during the driest part of the year, though if such a hazard exists it is best to keep a belt of land ploughed along the boundaries.

The best shelter trees are those that are indigenous and adapted for the purpose, such as the *Markamia platycalyx* Sprague, in Uganda and the *Andira inermis* HBK., of the West Indies. All should be selected for their resistance to wind and pests and diseases, also for their ultimate use for firewood, building materials, and timber, as they require thinning out, or when the purpose for planting them no longer exists.

The successful planter is the one who has the ability to look ahead. The economical life of a coffee tree depends on circumstances, and in many cases it may not be more than fifty years. At this time land must be cleared, and replanted after proper rehabilitation of the soil. Since young coffee cannot be developed successfully under mature shade trees, these must be uprooted and cleared as well, and if their timber is such as to be of value, then the sale or use of this may well pay for the whole replanting programme.

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Chapter VI

THE PROPAGATION OF COFFEE FROM SEED

Reasons for Selection

Until recent years, all coffee plants used for commercial planting were raised from seed, and most planters still use seed today. They decide what species or variety of coffee they want to plant, and those who are wise take care to obtain the seed from the best possible source. It is usually bought from a plantation with a good name, where the trees are old and healthy.

Ripe and perfect berries are sought, and these are plucked for seed and carefully pulped by hand or in a hand pulper. All the deformed and small seeds are then discarded, and the bold, fresh, heavy and sticky parchment coffee is rubbed in wood-ashes, partially dried in an open shed, and sown without delay. Those who are not so wise obtain their seed from the nearest place. They scoop a bucketful from a tank of pulped and fermented coffee and sow this without more ado. Even the wise can learn from the modern practice which research has proved so necessary during the last few decades.

To begin with there is a myth to be exploded regarding the use of seed from old trees. Seed from the first crop of a young tree is just as good because the inherited characters are the same. In actual practice, however, one waits for a young tree to prove its qualities before using its seed. This alone, then, is the reason for taking seed from old trees. It does also happen to be a fact that pulped and fermented parchment coffee will germinate as easily as hand-pulped unfermented coffee. It is as good, provided the seed is not damaged, and has been picked over to remove imperfections.

Inquiry has shown that in most plantations, surprisingly large areas of planted coffee do not bear economic crops over a period of years. For some reason or other, usually connected with patches of poor soil, or the ravages of pests and diseases in the past, the coffee bushes no longer have the stamina to bear as they should. Such areas should be ruthlessly uprooted, and either replanted after the soil has been brought into proper shape, or devoted to bananas or Napier (elephant grass) *Pennisetum purpureum*, to provide mulching material for the better areas of the plantation. Beyond this, it has also been shown that among the better trees in the healthy blocks of an average plantation there are often those which are continuously outstanding in their performance. About two-thirds of the trees may be relying upon one-third to bring the total yield on an estate to a satisfactory amount.

Research, and counts of yields of trees on plantations on Kilimanjaro mountain—though these plantations are considered to be some of the best in East Africa—appear to confirm that most of the crop is borne by trees in the minority, i.e., 20 per cent of the crop is found to be given by 5 per cent of the trees, or 66 per cent of the crop by 25 per cent of the trees, proving that about 75 per cent of the trees are uneconomic.[6] One must be careful in regard to such statements, however, and add the words 'in any one year', because an examination of the table on page 91 will show that the rhythm of bearing differs according to the tree, often irrespective of seasonal influences. Many

trees which bear a poor crop one year will be the best yielders in the following year. It is not easy to obtain regularity of yield from inherent characters alone. An impetus once given to a tree to bear a bumper crop in any one year is followed by a rhythm of 'on' and 'off' years, irrespective of whether the season is a good one or not, and not always corresponding with neighbouring trees. In other words a percentage of trees may be out of rhythm with the others, and for this reason they may bear good crops in the 'off' years in a rather unexpected and surprising fashion.

Planters are prone to ask why anyone should select better-yielding strains of Arabian coffee when the trees normally bear well, and often overbear their strength. Overbearing is another matter and it has its causes, but abnormal yields are borne usually at the beginning of a coffee tree's life, or at odd times when the climatic conditions are especially favourable. Throughout the life history of an ordinary plantation of coffee trees it is difficult to maintain good health and good yields in successive years. The aim should be at selecting mother trees with an inherent stamina, which may allow them to bear good yields as regularly as possible without so much exhaustion; not exceptional yields, nor poor yields, but a good economic average all the while.

If by obtaining clonal seed, or clonal plants from selected parents, a whole coffee plantation can be composed of such trees, then the average annual yield might be doubled. Would this not be satisfactory to the owner? Would he not rather have a steady and a better average yield than one year's surfeit followed by two years of poverty? He could then plant a smaller area and harvest just as much if his trees all had a pedigree.

Selection of Mother Trees

This is not wishful thinking, for it has been proved that there are outstanding trees of Arabian coffee among the common average on most plantations in East Africa, and a considerable effort has been made at the Lyamungu Coffee Research Station to propagate them for distribution purposes. An account is given of this work in reports covering the whole period of this station's existence, from the year 1935 onwards. By 1939, hundreds of selected trees had been tested, in many cases for six successive years, and one hundred had been further examined for the general qualities of the cured bean, except roast and liquor. This involved (1) the measurement of adequate samples from each tree in regard to the quantity of parchment and clean coffee per unit sample of fruit; (2) the percentages by weight of clean beans passing through screens of varied mesh and width of bars, corresponding to the screens used in curing works; and (3) the weight of bean and its density.

Of all the trees examined until then, only three met the rigid requirements, in that they were outstandingly good in yield, regularity of yield, out-turn and liquoring quality. Five more were found to be very good in regard to yield, or liquoring quality, and seven more were quite good in respect to both qualities. (*See* Table.)

Of course, it was expected that many of the mother trees would prove erratic in later years. Some, perchance, might have been standing in pockets of richer or moister soil, or had been planted near decaying organic matter of which visual traces had disappeared. In spite of these probabilities, the efforts met with success, and mother trees of outstanding quality were found, which was an achievement of great merit.

THE THREE BEST ARABIAN TREES

Yields calculated in cwt. per acre:
1 acre = 0·4047 hectares.
1 cwt. = 50·848 kilogrammes.

Tree No.	*Average yield over 5 years in cwt. of clean coffee per acre*	*Bean characters*			*London liquorer's report for two years*
		Weight in grammes	*Volume in c.c.*	*Specific gravity*	
L 1. ...	19·32	·170	·133	1·28	Fine to good
N 37. ...	22·24	·183	·141	1·30	Good
N 197. ...	21·21	·193	·150	1·29	Good

The work has been continued, and while many more mother trees have been listed for future propagation, the next step was to discover whether the seedling progeny would be as good as their parents.

In this work the station has not been so fortunate because the seedlings have shown neither quite such a regularity of yield nor such high yields as the selected parent trees. The causes are obscure, and may largely be due to the fact, as is admitted, that the land on which the seedlings were planted was not first-class, since it had been used for previous plantings and had not regenerated its full fertility. The Lyamungu station is neither on the best part of the mountain for ideal climatic conditions nor at the best altitude for Arabian coffee. It is too far west along the slopes, where the rainfall is likely to be erratic. If the mother trees were chosen and tabulated on plantations where the conditions were better, then one could assume that the seedlings might also give more regular yields than under the poorer conditions at Lyamungu.

However, this is mere conjecture, and the only other reason one might put forward is that it takes young trees some years to settle down to greater regularity and higher yields if these factors are inherent within them. Since this is so, the case for taking seed from old trees which have had time to prove themselves, holds good.

The following table begins to prove this point, for it shows that nine-year-old progeny from the selected mother trees have nearly doubled the average yield of the fifth year, and it is obvious that the yields were still growing heavier even in the ninth year. Some have very nearly caught up to the average yields of their parents, as doubtless they will in time. The records were taken from some trees that were planted on poor soil, and this is reflected in the yields, so they must not be condemned as poor yielders without closer inquiry. (*See* Table.)

It must not be forgotten that a mother tree that does well in one environment might not grow so well in another, in which case ecotypes or special strains might be developed by selection to suit different environments. This would be a tedious business in regions which, because of their uneven or short rainfalls, and high ranges of temperatures, would be, in fact, unsuited to Arabian coffee, and not worth the task.

The inherent characters of the mother trees in Tanganyika were likely to be mixed, so that the progeny could not be expected to grow true to type.

YIELDS IN CWT. PER ACRE OF CLEAN ARABIAN COFFEE

Old parent trees Average yields at site		*Average yields of young seedling progeny at Lyamungu*					
		Tree number	*5 years*	*6 years*	*7 years*	*8 years*	*9 years*
19·32	5 years	L.1	3·20	5·07	4·98	5·97	6·41
21·21	5 years	N.197	1·77	3·22	3·15	4·42	4·95
7·13	7 years	F.502	4·62	4·69	6·35	6·08	6·96
15·00	5 years	P.280	4·60	4·64	5·95	5·43	6·18
11·88	5 years	P.313	4·51	4·51	5·83	5·65	6·38
12·32	5 years	P.348	3·13	3·37	4·28	4·32	4·89
13·17	5 years	P.147	2·70	2·97	3·98	4·10	4·64
13·34	5 years	P.190	1·63	1·96	2·62	3·14	3·48
16·83	7 years	N. 39	2·78	4·46	4·74	5·15	5·96
15·04	4 years	H.133	3.07	4.77	4.37	5.34	5.75
9·39	7 years	F.839	3·52	5·49	5·24	6·21	6·41
7·50	7 years	E. 59	2·17	3·23	3·59	4·02	4·23
15·07	4 years	H. 1	4·00	5·97	6·19	7·25	7·67
8·76	7 years	F.840	4·08	6·06	5·81	6·94	7·31
13·75	7 years	N. 69	3·44	4·84	4·39	6·02	6·17
15·20	7 years	N. 50	2·91	4·23	3·83	5·30	5·40
6·57	7 years	E.665	2·28	3·32	3·36	4·46	4·62
11·23	7 years	N. 81	1·32	2·19	2·07	2·94	3·42
18·38	7 years	R. 3	1·38	2·38	2·19	3·23	3·50
	Mean yields	...	3·01	4·08	4·36	5·05	5·49

Note.—The above figures have been extracted from the Lyamungu Research Station Reports for the years 1946 to 1950. E = Boloti, F = Kikafu, H = Machame, L = Kibosho, N = Kilema, P = Mbosi, and R = Machame.

Secondary selections were carried out in the progeny plots; to give an example, F.502/1 yielded at an average rate of 13·67 cwt. of clean coffee per acre, whereas the average for all the seedling progeny of this mother tree was calculated to be 9·87 cwt. per acre in 1949.[6] The second generation of the tree F.502/1 must now be assessed by both vegetative and seed propagation, to prove that the exceptional yield was not on account of a soil condition.

The recorded yields from the seedlings of thirty-six mother trees over a period of eight years show that there were marked differences in cropping capacity. Seedlings of some of the trees consistently gave higher yields than the others, as the following two tables will show:

RECORDS OF INDIVIDUAL TREES WITHIN THE SEEDLING PROGENY OF VARIOUS MOTHER TREES OF ARABIAN COFFEE AT LYAMUNGU

Tree No.	Cwt. of clean coffee per acre					Mean of 5 years 1946–50
	1946	1947	1948	1949	1950	
F.502/1 ...	11·54	19·01	3·61	20·55	1·50	11·24
F.502/2 ...	13·66	14·93	0·07	14·73	9·08	10·61
F.502/3 ...	15·70	8·06	15·69	13·86	21·61	14·98
F.839/1 ...	9·76	16·80	1·07	23·02	6·58	11·45
F.839/2 ...	7·47	18·16	7·71	9·67	13·49	11·30
F.839/3 ...	13·15	16·38	5·44	27·39	11·88	14·85
F.839/4 ...	2·21	10·27	2·45	20·48	3·32	7·75
F.839/5 ...	13·41	9 84	3·21	16·48	7·85	10·16
F.839/6 ...	1·61	13·66	5·12	14·81	16·80	10·40
F.840/1 ...	2·80	11·96	4·51	20·23	6·68	9·24
F.840/2 ...	4 07	10·27	7·79	23·45	6·28	10·37
F.840/3 ...	6 87	34·54	0·77	19·85	9·10	14·23
F.840/4 ...	7·64	27·32	2 35	26·14	7·74	14·24
F.840/5 ...	12·81	13·32	2·58	23·76	1·17	10·73
F.840/6 ...	3·22	20·11	6·72	15·31	4·85	10·04
H. 1/1 ...	6·62	25·03	7·00	27·67	6·95	14·65
H. 1/2 ...	10·52	18·92	3·42	28·05	4·96	13·17
H. 1/3 ...	1·78	29·70	4·09	20·52	21·44	15·51
P.280/1 ...	12·56	16·89	6·17	11·72	8·73	11·21
P.280/2 ...	9 93	9·76	13·32	5·58	6·17	8·95
P.280/3 ...	5·26	7·13	0 80	18·45	2·02	8·85
P.280/4 ...	6·11	10·35	2·80	18·04	3·52	8·16
P.280/5 ...	6·96	15·78	1·67	13·53	4·66	8·52
P.280/6 ...	6·96	16·29	0·58	17·13	3·80	8·95
P.313/1 ...	11·29	11·46	10·99	11·03	19·94	12·94
P.313/2 ...	5·52	20·96	4·16	20·07	4·76	11·09
P.313/3 ...	8·40	20·28	5·73	13·95	10·16	11·70
P.313/4 ...	3·65	15·44	0·39	19·68	10·12	9·86
P.313/5 ...	4·33	13·24	1·59	17·04	5·13	8·27
P.313/6 ...	11·23	15·86	1·18	17·11	4·51	9·98

RECORDS OF INDIVIDUAL TREES WITHIN THE SEEDLING PROGENY OF VARIOUS MOTHER TREES OF ARABIAN COFFEE AT LYAMUNGU

Tree No.	*Cwt. of clean coffee per acre*			*Mean of 3 years 1948–1950*
	1948	*1949*	*1950*	
H.61/65 ...	8·02	16·26	4·84	9·71
H.61/66 ...	9·93	10·96	5·70	8·86
H.61/67 ...	18·79	7·92	5·30	10·67
H.61/68 ...	16·79	18·67	17·97	17·81
H.61/69 ...	14·71	9·45	13·81	12·66
H.61/70 ...	10·84	11·30	5·02	9·05
H.61/71 ...	30·33	7·45	32·17	23·31
H.61/72 ...	6·52	14·98	1·25	7·58
H.61/73 ...	11·33	9·08	6·47	8·96
H.61/74 ...	14·60	12·79	15·57	14·32
H.61/75 ...	19·56	12·36	25·62	19·18
H.61/76 ...	10·87	15·92	7 80	11·53
H.61/77 ...	18·08	11·55	5 03	11·55
H.61/78 ...	21·49	6·93	12·76	13·73
H.61/79 ...	9 33	20·48	16 05	15·29
H.61/80 ..	31·61	9·20	36·91	25·91
H.61/81 ...	20·18	10·99	14·60	15·25
H.61/82 ...	2·07	27·47	6·21	11·92
H.61/83 ...	3·81	30·93	5·14	13·29
H.61/84 ...	3·18	13·50	6·82	7·84
H.61/85 ...	5·61	5·73	12 22	7·85
H.61/86 ...	1·85	17·30	8·57	9·24
H.61/87 ...	4·71	17 53	10·05	10·76
H.61/88 ...	14·99	9·12	20·78	13·76
H.61/89 ...	8·32	28·44	1·86	12·87
H.61/90 ...	2·72	27·89	2·71	11·10
H.61/91 ...	5 08	34·52	4·84	14·81
H.61/92 ...	3·01	34·10	3·88	13 67
H.61/93 ...	4·16	32 11	8 39	14 89
H.61/94 ...	3 90	18·78	6 28	9·65
H.61/95 ..	1·88	7·08	8 89	5·98
H.61/96 ...	8·24	29·01	5 05	14·10

Extracted from Report of Lyamungu Research Station 1950.

In addition to the selection of mother trees, and their progeny testing, the yields of a great number of other selected trees of 'Kent's' and of *Bourbon* varieties of Arabian coffee were calculated over a period of years and tabulated as on page 95.

'KENT'S' SELECTIONS—SINGLE-STEM PRUNING

YIELDS CALCULATED AS CWT. OF CLEAN COFFEE PER ACRE

Tree No.	*1938*	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*1948*	*1949*	*1950*	*Mean of 13 years 1938–50*
KP.146	25·14	15·36	31·23	7·98	12·90	12·05	17·06	3·82	1·70	11·63	15·31	2·72	2·89	12·29
KP.147	28·17	3·75	8·23	11·29	1·53	10·78	7·72	12·90	Trace	6·45	1·26	7·14	4·50	7·98
KP.151	8·60	12·11	7·38	8·06	1·36	3·73	12·30	7·38	4·92	8·99	9·03	8·83	4·33	7·46
KP.154	12·71	17·74	9·33	13·75	0·59	12·30	2·38	11·46	1·10	22·15	30·56	3·78	23·59	12·42
KP.163	19·43	22·34	10·95	5·77	13·58	13·24	17·06	3·31	3·82	16·80	13·56	10·67	10·69	12·40
KP.164	9·20	12·28	6·45	5·77	5·01	5·52	17·65	3·22	8·32	25·88	31·04	13·82	31·40	13·50
KP.176	9·33	12·33	15·95	9·08	0·59	2·21	8·74	0·17	4·33	9·08	4·66	7·22	6·36	6·93
KP.204	8·01	14·70	7·81	16·12	1·78	10·78	10·95	10·01	14·68	18·24	3·71	22·24	0·34	10·72
KP.214	6·79	28·17	1·27	11·63	6·36	5·86	5·60	—	0·59	5·18	—	8·89	3·39	6·44
KP.215	3·25	30·35	8·66	6·11	5·09	13·15	28·43	6·28	14·68	21·81	4·78	26·28	5·01	13·38
KP.218	8·26	27·05	6·87	1·78	3·82	9·08	13·24	3·31	8·49	13·24	3·91	22·82	5·43	9·79
KP.226	7·10	27·43	6·19	10·95	—	6·70	6·79	1·78	3·56	4·67	7·86	2·94	5·94	7·07
KP.227	11·90	22·49	16·29	17·48	0·93	12·81	12·64	Trace	4·92	16·55	0·29	13·42	10·27	10·77
KP.228	13·39	25·35	7·81	8·15	0·85	8·74	7·72	5·69	6·19	13·49	1·70	16·11	5·86	9·31
KP.231	14·37	16·86	25·20	1·02	3·31	11·37	19·26	4·58	5·60	17·23	14·29	24·16	9·33	12·81
KP.260	7·84	12·87	8·32	11·96	2·80	10·52	12·64	11·71	9·25	22·83	1·60	33·76	2·38	11·42
KP.261	9·57	11·54	10·01	3·39	2·72	7·21	10·78	6·28	7·81	7·64	12·26	5·71	10·52	8·11
KP.262	11·20	14 43	12·13	11·63	0·42	20·79	7·64	15·10	10·61	16·97	1·78	8·36	9·16	10·79
KP.263	10·98	19 46	7·01	16·38	1 02	12 13	10·86	4·07	6·79	8·49	5·94	8·79	8·49	9·26
KP.265	13·10	14·62	9·33	9·33	3·31	19 86	13·92	7·64	18·16	14·60	20·13	9·88	23·93	13·68
KP.266	9·90	10·95	8·57	5·43	0·34	6·45	12·47	3·48	17·74	6·53	14·78	5·13	16·97	9·13
KP.281	8·25	12·24	7·72	0·08	0 76	11·80	15·19	0·93	4·92	2·72	6·92	20·50	17·57	8·43
KP.285	9·42	12 30	6·87	18·75	1·53	16·46	15·10	3·14	14·51	9·50	12·39	15·50	19·77	11·94
KP.289	8·35	11·83	10·10	13·41	0·17	13 58	13·15	3·48	7·64	21·38	2·68	19·11	3·31	9 86
KP.352	9·05	22 01	0 68	14·17	—	11·63	6·96	4·92	6·02	11·12	18·05	10·65	20·79	10 47
KP.362	7·41	13·10	11·12	19·52	3 73	15·78	3·90	11·29	3·65	15·02	22·79	7 01	22·49	12·06
KP.405	6·74	14 70	2 46	2·80	2 72	12·13	15·02	5·26	10·10	17·23	28·60	18·00	24 52	12·34
KP.406	9·62	10 93	9 33	4·16	4 33	14·93	14·09	6·87	10·78	11·37	28·49	14·80	19·09	12·21
KP.409	9 88	13·88	5·35	9·25	3·99	18·16	10·44	8·83	11·80	10·78	19·39	11·88	23·17	12·06
KP.412	10·01	13 69	7·64	13·58	2·80	9·84	7·89	8·57	2·63	12·81	12·61	13·39	18·67	10·32
KP.414	10 52	11·76	7 02	6·62	1·78	10·61	6·70	6·45	7·38	8·74	24·77	7·83	23·76	10·30
KP.423	10·49	14 15	10 95	17·99	5·94	29·62	3·99	20·03	7·55	29·02	8·16	19·35	4·84	14·01
KP.466	8·68	12 36	6·78	14 51	0·34	15·10	8·32	9·08	1·19	14·51	12·38	22·93	10·01	10 48
KP.512	10 27	11·15	2 89	15 78	2·12	15·78	10 36	7·04	6·62	9·25	18·16	22·08	6·36	10·60
KP.518	5 74	14 87	2·29	13 07	3 99	10 52	10 18	6·70	1·78	8·57	8·68	2·70	14 34	7·96
KP.532	8·51	12·51	9·50	19 52	3·14	13·92	11·96	1·10	4·75	15·53	20·47	14·38	15·44	11·59
KP.683	18·35	12 47	6 62	15 61	2 04	16·29	4·24	14·93	0·51	9·25	11·36	15·67	12·30	10·74
KP.685	11 56	12·83	6 11	11 96	0·85	12·98	6·53	15·95	3·39	15·02	10·63	24·47	10 18	10·96
VC.276	7 41	14·19	14 85	6·70	8·32	8·83	9·08	4·07	9·59	7·13	16·62	2·27	13·75	9·45
VC.363	7·64	14·91	5·60	9·50	12·47	12·73	0·59	13·32	5·35	3·31	15·96	0·08	10 95	8·65
VC.364	6·93	14 90	8·40	8·49	13 49	6 28	0·34	14·09	6·02	7·89	21·91	1·20	6·02	8·92

OTHER SELECTIONS OF ARABIAN COFFEE

YIELDS CALCULATED AS CWT. OF CLEAN COFFEE PER ACRE

Tree No.	*1938*	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*1948*	*1949*	*1950*	*Mean of 13 years 1938–50*
11	8·99	4·56	7·81	21·30	8 23	33·35	—	41·66	0·85	26·39	10·37	10·35	—	13·37
33	4·41	13·85	3·56	22 15	6·53	25·71	—	54·05	—	29·11	43·09	11·21	14·13	17·52
55	14·09	3·79	13·92	13·24	9·84	23·59	—	38·27	2·04	49·73	1·28	25·08	2·34	15·17
71	14·17	1·64	10·61	21·55	16·63	23·93	1·19	44·89	0·51	42·26	1·15	20·04	1·17	15·36
179	13·32	2 04	6·53	21·30	2·12	37·75	3·05	39·03	—	25·03	1·47	6·88	1·29	11·52
188	15·51	—	10·27	15·02	11·96	17·14	1·27	44·21	0·59	45·06	5·71	24·94	0 88	14·81
197	13·72	1·36	10·86	14·43	7·21	21·64	8·74	50·26	0·59	27·24	20·80	13·43	3·17	14·88
200	13·88	0 08	9·25	13·41	12·98	26·98	—	45·40	—	38·36	3·39	24·22	0·82	14·52
255	13·85	—	10·52	19·86	3·05	19·77	—	49·90	—	41·24	4 14	29·25	2·52	14·93
339	16·97	0·17	13·24	7·81	11·96	27·83	—	42·85	1·95	34·54	17·35	22·38	2·17	15·32
448	15·24	1·10	14·60	10·10	5·18	26·48	—	46·16	6·70	46·08	1·65	31·55	Trace	15·76

The yield table of 'Kent's' coffee exhibits remarkable variations in yield which do not necessarily follow the 'on' and 'off' seasons of the locality. During 1939 the yields of all the 'Kent's' selections except one, were good, but after this exceptional year a rhythm is shown of poorer yields, following good yields, for one or more years. Some trees show a very good average at the end of thirteen years. This was especially the case among the other selections where, in spite of two total failures in the bad years of 1944 and 1946, tree No. 33 gave an average yield of 17·52 cwt. of clean coffee per acre. Imagine a plantation composed wholly of such trees! The average yield of many East African plantations is only 3–6 cwt. per acre.

There are so many uncontrollable factors when the trees are trained to the single-stem method which was the method in use when most of these records were made. The pruning may vary in any one season in favour of one tree or another, owing to the uncertain human element, and by coincidence, a tree or a plot may be pruned rather more severely than others for two successive seasons. It is surely well-nigh impossible to equalize the amount of leafage and bearing wood while the pruning knife is accomplishing its task. Enough has been said, however, to show how wise it would be to choose seed from proved mother trees, and their tested progeny, and also to indicate how a first-class seed strain may be evolved by selection and rogueing over a period of years. The fact that Arabian coffee is self-fertile should help in building up such a good strain from mass selection—a strain which one could almost call ecotypic, acclimatized and clonal.

Many of the so-called varieties of Arabian coffee which have a name for high quality and good yield in one country or another, exhibit common factors and do not appear to be so good when they are taken to a new area and grown side by side with other strains. The product from Blue Mountain Jamaica, for instance, is very good when it comes from Jamaica, but when seed from this is sown in Uganda it does not appear to grow so well as the local forms of Bourbon coffee, nor is the product outstanding. A great deal of the cup quality of coffee is given by the environment in which the coffee is grown, and also by the method of treatment. The way in which the coffee trees prosper and yield in any one country may be brought about to some extent by unconscious natural selection in previous years from trees which do best in that locality.

The practice of taking seed from old and proved trees has been in vogue since the beginning of coffee planting, and in all old plantations there are many gaps where trees have died out. A proportion of these deaths may have occurred because the trees lacked stamina, and those that survived and gave such good returns may have been more suited to the locality than the others. In such a way does unconscious selection achieve what might be termed acclimatized strains over a long period of years. This has nothing to do with mutation, or with a deliberate selection for disease-resisting characters, though there might be assistance from chance hybridization between true varieties of coffee which have been imported and planted in the same locality.

The point the author is trying to make is, that local strains of Arabian varieties may be adapted to their particular localities and not prove as good elsewhere. This may also apply in future to new high-yielding strains which have been deliberately selected in India or East Africa. When taken elsewhere they may not prove as good.

It is not generally advisable, therefore, to import a well-known strain from elsewhere when there is plenty of coffee of the same variety grown in one's own locality from which a local high-yielding strain may be developed by selection. There is a danger that one might be disappointed by the behaviour of the imported coffee. There are exceptions to this rule and 'Kent's' coffee is one of them. One might now call this coffee a distinct cultivated variety as opposed to a strain to which the name of the country or the locality is given.

The knowledge that Arabian coffee is self-fertile brings understanding of how much easier it is to keep a strain pure. The likelihood is that seed obtained from a tree has been fertilized by its own pollen, and if seed is taken from the trees in the middle of a block of clonal coffee the chances that self-pollination has taken place are almost 100 per cent. Natural cross-fertilization is generally brought about by the agency of wind.[10]

Seed Selection in India

'Kent's' coffee originated in 1911 and was propagated on Mr. Kent's estate at Doddengoodda near Aldur in Mysore, India, and it quickly became renowned for its vigour and its resistance to pests and diseases. About this time Jackson's coffee also originated in much the same way on an estate belonging to a Mr. Jackson in the same neighbourhood, but this gained nothing like the same reputation, and is seldom heard of today.

From the inception of research in Mysore, now carried on by the Research Department of the Indian Coffee Board, work has been carried on to improve the local strains of Arabian, and later of robusta coffees. The methods used have been (*a*) to select mother trees and to self these desirable types, (*b*) to hybridize promising parents, (*c*) to hybridize existing material and search for new combinations, and (*d*) to self desirable selections. Mother tree selection has been considerable, and a great deal of attention has been given, as at Lyamungu, to improve 'Kent's' coffee and find better clonal material. Trees have thus been bred, chiefly by selection, which are at least outstanding in Mysore, and much dependence is put on the propagation from seed of their Arabian strain S.288, and their robusta strain S.274. There is a good deal of 'Kent's' blood in the former, and it is said to exhibit the same resistance to disease.

Seed Selection in Java

On account of leaf disease and borer beetle attack, Arabian coffee cultivation was soon discontinued in Java except in favourable localities at some of the higher altitudes. Robusta has since been grown instead, and throughout the years a great deal of work has been done to select mother trees from imported and local strains, and also to hybridize varieties and species to increase yields and gain disease-resistance. Indeed, so many hybrids and selections have been made, and given numbers and names, that it is easy to become confused. The emphasis has been on grafting various stocks with material from selected mother trees or from special hybrids, it being essential to graft the hybrids because they would not grow true from seed. The building up of clonal seed, or special strains of seed, has also been given attention.

Seedlings versus Cuttings

At this point it is necessary to include the results of a test to discover whether seedling coffee plants are better than clonal plants propagated from cuttings for planting in the field. For some years the clonal material propagated by cuttings gave higher yields at Lyamungu. The vegetative propagation preserved the characters regarding good yield as might have been expected, but, in course of time, the yields evened up until there were no significant differences between the two. In fact, there was a tendency in some of the later years for the seed plants to out-yield the clonal plants. It will be interesting to discover how this test will develop in future years. Experienced planters have often thought that coffee is sensitive to the condition of its roots. Some argue that coffee has tap-roots which must not be damaged, cut, or bent; others say that coffee will develop new roots no matter what happens to its old ones.

The author has favoured the former protagonists, for he has frequently observed the exhaustion of coffee plants on account of careless planting. He has dug up trees that have died of exhaustion, and invariably the main geotropic roots have been bent, or twisted, whereas the healthy trees have had proper root systems. For this reason one is apt to be a little sceptical of the advantages of vegetative reproduction, and it may well be that this test will prove that trees derived from seed having a natural and normal root system will give better service in the long run than the best clonal material propagated by cuttings.

Naturally for the sake of research and experiment, clonal material is imperative, and propagation by cuttings has proved easier than any other method of vegetative reproduction. Commercial planting is a different matter, however, and no big-scale planting of plants derived from cuttings should take place until tests have proved over a longer period of years that clonal material of this kind pays. There is, of course, a great deal more bother and expense involved in the raising of plants from cuttings. Provided a good strain of seed can be found, and the coffee is planted in a satisfactory environment, then this should be good enough for most undertakings.

Selecting for Robusta Seed Progeny

In most cases, the flowers of *Coffea canephora* are self-sterile, and even when they are not and flowers can be fertilized from the tree's own pollen, the yields given by these trees are rarely comparable with those that have received pollen from other trees.

There is a danger, therefore, in carrying the selection of a single clone too far, and of propagating one clone alone for planting in the field. If clones could ever be purified and vegetatively propagated, it would be necessary to plant alternate lines of the different clones to ensure cross-fertilization and good yields. Fortunately, however, among all the widely varying forms of robusta coffee there seem to be groupings among which certain characters are dominant. Hence we get a stiff upright growth known as *Coffea ugandae* in Java, but as the No. 9 selection in Uganda, or the spreading shrubby growth known as Quillou coffee in Java, but as 'Nganda' in Uganda. There is also the *Coffea congensis* of the Congo region, which has a stunted small-leafed growth and seems to prefer a high water-table. This is considered by

By courtesy of the Royal Institute for the Tropics, Amsterdam

A robusta coffee nursery at Tanah Redja estate, Java, with part of the shade removed

PLATE XVII

many to be just another form of *Coffea canephora*, known otherwise as robusta coffee, and it is said by Dutch authorities to be wholly resistant to leaf rust disease.

Much of the selective work with robusta in Java was done in the beginning with a view to preserving and propagating the good characters by grafting. Ferwerda,[3] however, summarizes a recent account of the work on robusta coffee by saying: 'In coffee breeding crosses are made nowadays between outstanding mother trees, and the progeny thus obtained are subjected to comparative tests. From them, new mother trees are chosen with which this selection process is repeated once or twice. After two or three such generations one arrives at progeny surpassing the original material in yielding capacity up to 50 per cent, and in regard to other properties. The outstanding strains are propagated on a large scale in clonal seed gardens containing grafts of both parents. Before planting the new seedling progeny on a large scale, it is important to test their local suitability. A few interspecific hybrids have also been used in commercial plantations but only to a limited extent. Some of the interspecific material is promising, but it has not yet gone beyond the experimental stage. The transference of pollen among those robusta plants which rely on cross fertilization is accomplished by wind.'

A great deal of selective work on robusta coffee has been done in Uganda of recent years. Thomas[9] states that the average yields from different progeny of selected spreading forms, tested over a period of seven years, varied in yield from 1,590 lb. down to 925 lb. of clean coffee per acre per annum. Heavier yields were obtained from some progeny of the erect forms, and two gave annual averages of 1,780 and 1,760 lb. respectively.

He goes on to record that robusta coffee in Uganda varies in vigour, in root systems, in habit and secondary branching, in leaf characters, flower characters and fruit characters. Vigour is associated with resistance to leaf rust disease; forms with bronze tips to their young shoots suffer less when exposed to drying winds. Diversity is natural since robusta coffee is mainly cross-pollinated.

In six selections out of seven, the robusta trees derived from self-pollination were less productive than those from open pollination. In a selection numbered '4', however, the progeny gave larger yields, and only in this case was the average bean-weight much larger than the progeny from the open pollinated parents. Thomas states that it is obvious that improvement may be secured by the selection of mother trees alone. Genetical differences, he says, seem to control the degree of self-incompatibility.

One does not have to go back very far—only a little more than half a century—to be astounded at the ignorance then shown by agriculturalists and planters throughout the world in regard to crops such as coffee, and the primitive methods they used in the cultivation of many plantation products. When Arabian coffee was planted extensively in Ceylon, the methods of treatment were poor, the planters seeking to progress by trial and error through a maze of misunderstanding. Seed selection has always been a natural impulse among intelligent individuals of all races, and with the advancing knowledge of recent years agriculturalists in most countries have devoted more thought to it and taken a greater interest. Hence we find that a good deal of selection work has been carried out and is proceeding nowadays with ever-increasing care and circumspection in most countries where coffee

is being grown; in Brazil, Central America, in Dutch, French, and Belgian territories, as well as in our own.

The Dutch in their East Indian possessions were among the first to start the improvement of coffee by different methods of propagation, including seed selection, and they carried out a vast amount of work which will be found reported in the older literature. They went in for a deal of hybridization, and much of the value of this earlier work is spoiled by the fact that it is based on doubtful determinations, and by confusion engendered by the hybrid nature of their material.

Some additional references are selected and given at the end of this chapter.

Estate Selection

It should now be fairly obvious that a planter is best advised in the first instance to obtain his seed, if possible, from tested progeny of selected mother trees in his own neighbourhood. He should refer his desires to the local agricultural authorities to discover what may be found near to his hand before he thinks of importing seed from some other country or distant region, no matter what species of coffee he desires to grow.

The selection and breeding of new strains is a very complicated business. It requires to be carried out over a long period of time and is both labour- and time-wasting. For these reasons the task should be relegated to technically trained people on central research stations, financed by the government or the local industry as a whole.

Beyond this the planter may keep his eyes open when walking through his own established fields for any outstanding and valuable difference among his trees. Coffee is known to mutate in various ways so that trees of different vigour and kind appear quite suddenly among planted seedling fields. Maragogipe and 'Kent's' coffee both arose in such a manner and both have been planted widespread. Even so, they might have been lost by careless handling on the part of the original finders, and it is far wiser to report a discovery of this nature to the local agricultural authorities. At least they can give advice, and arrangements may be made so that the planter does not lose a potential benefit from the sale of valuable seed.

Viability, Storage and Transport

VIABILITY OF COFFEE SEED

It is probable that the seeds of all the species and varieties of coffee lose their viability fairly quickly. The author is unaware of tests having been made with the seed preserved in dried and shrivelled fruit, but tests of Arabian seed in parchment were made at Lyamungu with the following results. The sowings were made at monthly intervals beginning seven weeks from the date of harvest, and the seed belonged to one clone of Arabian coffee. (*See* Table.)

The experiment was carried out under ordinary nursery conditions. It showed that after the seed had been stored for a period of twenty-one weeks from harvesting, the germination percentage began to fall, and after thirty weeks the fall became more marked. As the seed increased in age, so did the time taken for it to germinate also increase, for whereas 7-weeks-old seed with a germination percentage of 95 per cent germinated in 10·1 weeks,

VIABILITY OF ARABIAN COFFEE SEED

Age in weeks	*Percentage germinated*	*Time taken to germinate in weeks from date of sowing*
7	95	10·1
12	96	15·7
16	94	11·6
21	87	16·1
25	60	23·1
29	62	16·3
34	27	16·7
38	40	23·0
43	24	23·3
47	22	26·0

25-weeks-old seed having a germination percentage of only 60 per cent took 23·1 weeks to germinate.[6]

STORAGE OF SEED

The percentage of moisture permitted in the seed depends on how long it is wished to store the seed before sowing.

Under the best possible conditions of storage, the life spans of different seeds vary, as also does their tolerance of dryness, and their response to temperature and humidity. The longevity of many seeds is increased by drying, but on the other hand there are seeds such as those of the citrus family which are definitely harmed by drying. Seeds stored under conditions of high temperatures and humidity may lose their germination power in a few months, whereas many kinds of seeds stored under favourable conditions may remain viable for as long as twenty years. Arabian coffee seed is known to lose its viability very quickly when it is stored without care.

According to Barton and Crocker,[2] the factors affecting the life of seeds in storage are moisture, temperature and gaseous exchange. When the humidity or the temperature of the air is high, the life of seeds can be prolonged by reducing the oxygen supply, as in airtight tins, provided their own moisture content is low.

Seeds can be air-dry in one locality and have a safe moisture content, but seeds air-dried in a humid region may have a dangerously high moisture level. Moreover, the humidity of the air varies during the year in any one place. For the purpose of keeping most seeds stored safely for a long while, and in particular before sealing them in containers to travel long distances, the percentage of moisture in the seed should be adjusted in the beginning to a known optimum level. A fluctuation in moisture content is believed to contribute to the degeneration of seed.

When the humidity of the surrounding air is about 35 per cent, seeds remain drier if the temperatures are high, i.e., round about those which might be found in coffee country. At 41–50° F. they absorb moisture at about the same rate at this level of humidity. Let the temperature fall to 50° F. when the relative humidity is from 55–76 per cent, then moisture absorption reaches its peak. The lower rates of absorption at these higher humidities have been found to be at 41° F. and 86° F., i.e., before and after the peak.

How does all this affect the germination percentage? After storage for five

months the germination power of some seeds is constant and good at temperatures ranging from 41° F. to 86° F., provided the humidity is between 35 and 55 per cent, although other seeds degenerate rapidly at temperatures higher than 41° F. At 76 per cent humidity, the germination power of most seeds remains good at 41° F., but declines steeply at higher temperatures.

With high rates of humidity the temperature must be low, so coffee seed should be kept in a cool dry store. Provided the air is dry, it should not matter so very much if the store temperature rises to 80° F. and more, though a cool constant temperature is generally the best.

TRANSPORT OF SEED

For the purpose of transport seeds should be packed 'open', i.e., in a box or a bag when they are partially or only air-dried; or sealed in air-tight containers if they have been oven-dried to moisture percentages of less than eight per cent. It is dangerous to pack air-dried or partially dried seeds in airtight tins. The author has always germinated coffee successfully when it has been partially dried under shade, and mixed with spent wood ashes and sown within a few weeks of harvest. Now that we have air transport there is no need to sow old or oven-dried seed for commercial planting or to pack it in air-tight containers, though for experimental purposes it might be desirable to keep special parcels of seed viable for as long as possible.

At Lyamungu it was found that Arabian coffee seed which had been pulped, fermented, and washed before it was shade-dried, gave similar results to seed which had been hand-pulped and not fermented.

As an example of the amount of coffee seed required, about 55,000 seedlings should be raised in the nursery for each 100 acres of land if the plants are to be spaced in the field 9 feet by 9 feet apart, including a surplus for supplies. Given an 85 per cent germination, 8,250 more seeds would be required to make up for those which were not viable, or a total of 63,250 seeds. According to Macmillan,[6] 960 Arabian coffee seeds and 700 Liberian coffee seeds each weigh one pound. Robusta seed is smaller so there would be more to the pound, and excelsa seed is about the same size as Arabian coffee. This means that about 66 lb. of Arabian seed would be required to establish 100 acres, depending of course on the moisture content and the weight of the seed.

RAISING COFFEE PLANTS FROM SEED

SELF-SOWN SEEDLINGS

The practice of taking seedlings arising from self-sown seeds that have fallen near old coffee bushes, and of using these for starting a nursery or for planting in the field, cannot be too strongly condemned. Only plants raised from the best selected seed should be used, and these should be grown under proper control in nursery beds. It is usual to sow coffee seed in its parchment covering, and to discard the rounded peaberry.

WHICH WAY UP SHOULD THE SEED BE PLANTED?

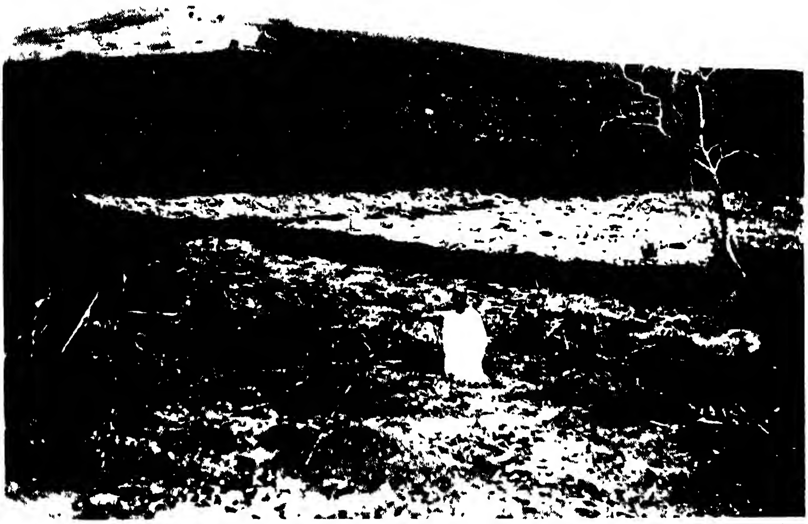
Many have wondered whether the half-rounded coffee seed should be sown with the flat side downwards. As the seeds germinate the hypocotyls lift the cotyledons out of the soil while they are still enclosed in their parchment

By courtesy of Licenciado Don Juan Rebolledo Clement of the Comision nacional del Café

Coffee nursery in Mexico

PLATE XVIII

By courtesy of Licenciado Don Juan Rebolledo Clement of the Comision nacional del Cafe



(*a*) Nursery area, Nantongo estate, Busiro District, Uganda. The man is standing in a hole to demonstrate its size in a newly opened area. The trees shading the coffee on the hillside are young *Hevea* rubber

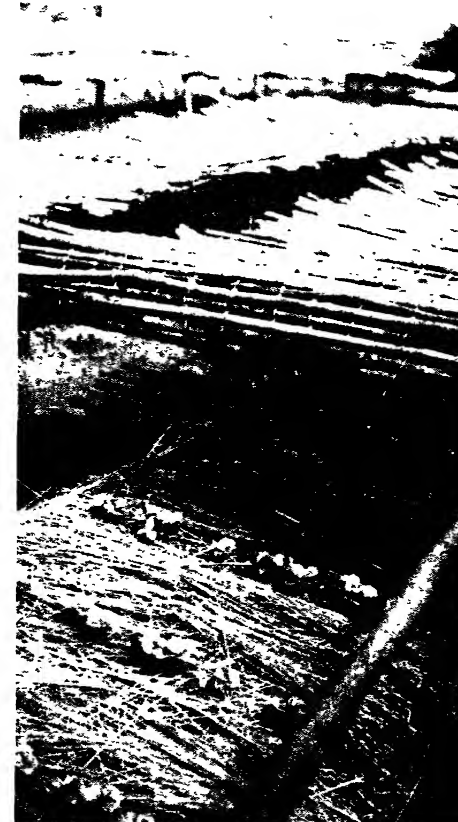
(*b*) Robusta coffee seedlings almost ready for planting, in Bukoba District, Tanganyika. They are hardened off to the sun and the soil is protected by a grass mulch

Photo by author

PLATE XX

(a) Arabian coffee tree var. *bourbon*, planted when it had six pairs of leaves, in Bukoba District, Tanganyika. Note how young first leaves have been held

Photos by author



(b) Arabian coffee germinating through grass mulch cover, Nyakato, Bukoba District, Tanganyika. Note low shade of home-made roller blinds and open pathways

PLATE XXI

coats, so it does not matter which side is uppermost when the seeds are placed in the soil. Soon after germination the parchment coat of a seed splits and the two leafy cotyledons unfold. Since most of the seed contents are thus lifted out of the ground after the young root has emerged, it is imperative that the seed should not be sown too deeply, and that the surface soil should be loose.

Raising coffee plants from seed is not difficult, and neither should loss of time occur in doing this, for when a new plantation is being opened up, the nursery is one of the first considerations. Seed is sown and the plants are being raised while the land is cleared and prepared.

PREPARING A NURSERY

Firstly a suitable piece of sheltered land must be found close to a water supply, and preferably flat or having a very gentle slope. It is unwise to place the nursery under trees or permanent shade, and neither should it be sited in a valley where there is likely to be a flow of cold air, or light frosts. The ground should be well dug and freed from tree roots or stones, but care must be exercised not to bring the subsoil to the top. It is best not to use manure unless the soil has been exhausted by crops such as maize or bananas. If manure is necessary, then it should be used sparingly, and be of thoroughly decomposed compost of good quality rubbed through a coarse sieve and forked into the top six inches of soil. The soil should not be limed or treated with chemical fertilizers, though a little bone meal, dried blood, or fishmeal might help to give it life.

For convenience the beds may be separated by three-feet wide pathways to give sufficient room for people to work in comfort and to pass one another when necessary. The beds should be constructed along the contour if the land is sloping, and be protected by a storm drain from any wash and flooding which might invade the nursery from higher land above the site. It will be necessary to reach over the beds for sowing, weeding and watering; hence their width should not be more than four feet. It is convenient to raise the beds a few inches and this can be done by using the top soil from the paths.

Most planters agree that coffee plants should be raised under shade. In most cases the shade is placed on a framework of posts, crossbars, and wires, sufficiently high to allow the workers to stand underneath. The actual shade is then arranged by placing palm leaves, Napier grass, or tough reeds over the top, and tying this material in position to prevent it being blown away by high winds. As the call for shade becomes less, so is the material reduced overhead by pulling some of it away. This is a somewhat tiresome method because it entails a lot of cutting, carting, and construction, together with major repairs when the posts begin to decay. Neither is it possible to remove all the shade during periods of dull weather, and the plants beneath may easily get overdrawn.

The author prefers a low shade no more than 1 ft. 6 in. above the beds, leaving the pathways quite free. Uprights may be spaced at intervals along the sides of each bed to support runners of wire or thin saplings, and these in turn will support eight to ten feet lengths of cane matting. The matting is made by tying split bamboo, Napier grass canes, dried Sorghum stalks, or strong reeds side by side, leaving interstices for the light to filter through. Since the mats should be wider than the beds, they will rest safely across the

runners, as would Venetian blinds if they were laid horizontally. They can be rolled aside in a moment or two in dull weather, or when watering and weeding are necessary.[4]

These locally made roller blinds have a long life, and there are several advantages in their use. If they are rolled aside at night the young nursery plants have the advantage of the air, and similarly, when they are rolled aside in dull weather or during rain, the plants have more light which is beneficial, and they do not suffer drip from the shade. Workers along the pathways have complete freedom, and are not prevented from carrying loads on their heads as peasant workers often do. When the young plants require hardening off to full sunlight it is easy to do this gradually by rolling the blinds aside during the mornings and late afternoons. It will be found that young plants grow more sturdily when roller blinds are used properly, than when they are grown under high permanent shade.

The same belief is held apparently at the Ruiru Coffee Research Station in Kenya, where low wires are stretched to form the rests on which the shade is laid about the same height above the beds. The shade is composed of loose laths of wood, split bamboo, or split sisal poles, and these are gathered up and placed on special rests at the ends of each bed when the shade is not required, or cultural operations are being practised. The loose slats can be laid closely, or a little distance apart, in accordance with the amount of shade required, and when dense shade is wanted, grass is laid on top. For ease of movement the author still prefers the roller-blind method of shade.

METHODS OF SOWING SEED AND TRANSPLANTING SEEDLINGS

There are two methods of sowing the seed and both have their advantages and disadvantages. One method is to sow the seed closely, in patches or drills, and prick the seedlings out into the nursery beds at a proper spacing almost as soon as the seed has germinated. The other method is to sow the seed spaced at the proper distance in drill rows, so that the young plants are moved only once from their nursery bed to the field. With both methods the seed should be sown about half an inch deep.

While the seed is germinating it is most important to keep the moisture in the soil at an optimum level. This is not always easy in dry weather when seeds have been sown at the proper spacing in sufficient number to raise say 110,000 plants to plant up to 200 acres of land at a 9 ft. x 9 ft. spacing, and to allow a reasonable surplus for supplying vacancies. If there is too much moisture the seeds may rot, and if the soil is ever allowed to get dry at the critical time of germination, the germ may shrivel and the seed be killed. Since it is difficult to ensure that a considerable area has the right amount of moisture while the seeds are germinating, many prefer to use the first method and sow the seeds thickly and then transplant the seedlings afterwards.

Seed should not be sown in a wet soil or a dry one. If there has been a heavy shower of rain it is wise to wait until the surface soil has dried into a moist but crumbly state. If the nursery beds have been constructed during dry weather, and the seeds are sown soon afterwards, then it is most important to see that the subsoil is moistened by a thorough soaking. It is no use sowing seeds in moist surface soil when the subsoil is bone dry. After the seed has been sown, and if successive showers do not fall soon enough to keep the soil moist, water must be given by can or by spray. There should be no

attempt to water if the soil immediately beneath the surface is dark in colour, though it must never be allowed to get too dry. When the seed has germinated and the young plants are growing fast, they will tend to dry out the soil at a faster rate and will require additional moisture. They should never, on any account, be allowed to wilt.

Watering is best done in the late afternoon, for there is more time for the water to soak downwards during the cooler hours of the night in the absence of intense evaporation. The water spray should be a fine one, so that the soil does not begin to wash away or get puddled on the surface to form a crust as it dries. To economize in water during drier weather, the author has found an inch-thick mulch of stiff dry grass of great benefit, and never harmful provided it is loosely laid between the growing seedlings so that it does not begin a rapid decomposition and thus reduce the nitrogen content of the surface soil. It should be laid a few hours after watering, and it is surprising how much longer the soil is kept at a comfortable moisture level.

Using a thin mulch of straw-like grass it is easier to control the moisture content of the soil over a large area and to economize in watering. It is thus possible to sow seed with greater safety at its proper and permanent spacing in the nursery beds, and obviate the necessity for transplanting. The author has mulched beds immediately after they have been sown, and as the seeds germinate they pass through the mulch and tend to push it to one side. It requires less labour to assist the seedlings through the straw than to cope with the extra watering that would otherwise be necessary. Since weeds are also depressed for a while, a reduction of weeding costs is another argument in favour of a grass mulch. There is no need to scuffle the soil since it never forms a crust.

If seed can thus be sown and plants raised economically at their proper spacing without following the patch method of sowing and the pricking-out afterwards, then the young roots are not disturbed or damaged twice in their lifetime and the seedlings grow on at a faster rate without suffering a check. Supposing, however, the patch method of sowing is used, then there are some other rules to be followed.

The germinated seedlings should not be transferred unless the soil is moist and crumbly, and they should be lifted and loosened carefully by inserting a trowel or a fork at depth. They are best transferred when the two seed leaves or cotyledons have grown to their full extent, though seedlings that have not yet dropped or split their parchment shells may also be transplanted safely. The longer the task is delayed, the longer the tap root grows and the greater the difficulty of transplanting without damage. When handling the seedlings they should be so gently treated that they are in no way bruised, and as few as possible of the finer roots broken. It will be noted that most of them have tap roots as long as four to six inches or more before the first seed leaves have unfolded from their parchment coverings.

The soil of their new abode must also be moist and crumbly, and the seedlings should be lifted and replanted without delay, and in such a manner that the tap roots are dropped into a deep enough hole so that they are not bent or crumpled. The seedlings may be inserted so that the cotyledons within their parchment shells are about half an inch above the surface of the soil, which should be gently firmed round the roots.

If special trowels are not available a dibber is often used, but there is the world of difference between a dibber used for planting cabbages, and the

kind of dibber which should be used for planting delicate coffee seedlings. A cabbage dibber is an old wooden spade handle cut short, with the stump of the shaft rounded to a point. This is pushed into the soil to make a hole, firming the soil round it to form a tube, into which the roots of the plant are dropped. A few jabs with the dibber round the plant firm it in position, though the plant may find its roots suspended in an air-pocket at the bottom of the hole. It is much better to make a flat, slender, but strong dibber from a piece of hard wood, shaping it with a flat handle, and using it like a trowel. The flat dibber is inserted vertically and the soil is drawn towards the operator, after which the roots of the young seedling are dropped into the hole, and the stem is held against the back of the hole at the right level. The soil is then returned and firmed with the fingers.

In delicate operations such as this there is nothing so efficient as the fingers. After the seedlings have been transplanted they should receive a light watering without delay.

SPACING IN THE NURSERY

Before considering the spacing of coffee seedlings in the nursery beds it is important to know the intentions of the grower. Does he believe in planting seedlings in the field when they have grown only six pairs of leaves and before they have started branching, or does he believe in planting older plants, either to plant as cut-back stumps, or to plant as young trees with branches for bending over to encourage a multiple-stem growth?

The author would never plant a seedling with more than six pairs of leaves in the field. He would watch his plants carefully to discover those that had been damaged by mole crickets or cut worms and supply new plants at once, rather than permit older plants to suffer the disturbance to their more extensive root systems, though this is doubtless a matter of opinion. A young plant is surely capable of withstanding the shock of removal better than an older one, and since its roots are smaller they may be arranged in the soil in the proper manner. Much of the deep planting that has taken place in East Africa in the past was on account of the long leggy plants which had been produced, and the anxiety on the part of the planter to lower some of their ungainly, unproductive lengths beneath the soil. The illustration of a young Bourbon coffee plant planted by the author in Tanganyika Territory, when it had only six pairs of leaves, shows that healthy and green leaves have been retained on the main stem, albeit the young plant has grown branches. If the plant had remained in the nursery until it grew to this size, all these leaves would have dropped, including those where the branches are forking outwards.

To return to the subject of spacing. If the seedlings are to be planted out with six pairs of leaves, then Arabian coffee seedlings should be spaced in the nursery 9 inches × 6 inches apart, robusta coffee 9 inches × 9 inches, Liberian coffee and excelsa coffee about 1 foot × 1 foot apart. If seedlings are to stay longer in the nursery until they have begun to branch, then they should be given a spacing sufficient to prevent the interlacing of their branches. This is just horticultural common sense, though few would agree that only twenty-one plants should occupy a nursery space 10 feet × 4 feet.

Fresh Arabian or robusta coffee seed should take about six to ten weeks to germinate, and it should require as many months to raise plants with six pairs of leaves in readiness for planting in the field.

By courtesy of the Kenya Information Office

Arabian coffee for African growers in Kenya. The plants are too thick and beyond their best planting age in the author's opinion

PLATE XXII

Photo by author

Making large round banana-fibre pots inverted on a post. Uganda. In fact a poor uneven specimen

PLATE XXIII

TREATMENT OF SURPLUS PLANTS FOR SUPPLIES

In order to supply vacancies in the field so that all grow with equal vigour, it may be wise to raise a number of healthy seedlings in baskets or pots, and have these in the nursery of the same age as those that have been planted. In many countries the containers may be wicker baskets or pots made of banana fibre, though there are cheap and modern holders made of treated papier-maché which might be as economical to use. There are also modern methods of compressing soil to the shape of pots, which might be found useful.

When using any basket or container a single seedling should be placed firmly in ordinary fertile soil, and the container filled to within half an inch of the top to allow for watering. The filled containers should then be arranged in rows, side by side, under nursery shade, on a hard floor of weathered cinders or gravel, and the interstices between the containers should be filled with fine cinders, gravel, or sand to prevent undue evaporation. The seedlings are best potted up soon after germination when the seed leaves have unfolded, and the closest attention given to watering so that the soil in the

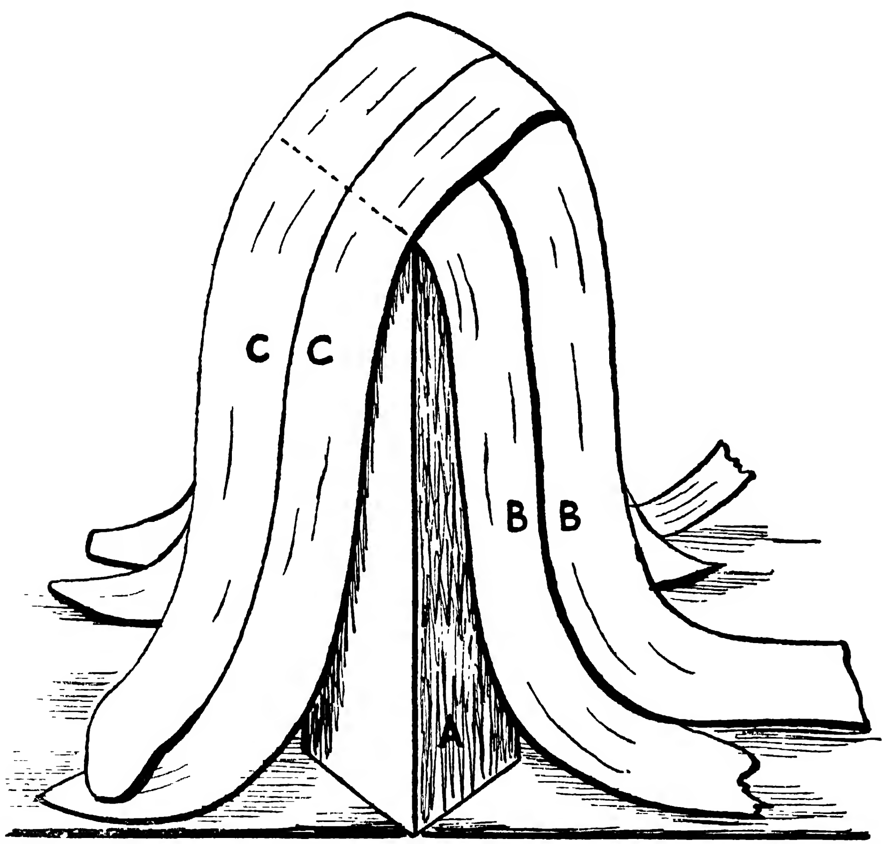


FIG. 4.—The making of banana-fibre 'pots': (*a*) Squared post to dimensions desired; (*b*)(*b*) Good strong pieces of banana fibre laid side by side over the top of the post; (*c*)(*c*) Two more strong pieces of banana fibre laid at right-angles over the first pair. All ends are bent downwards against the post.

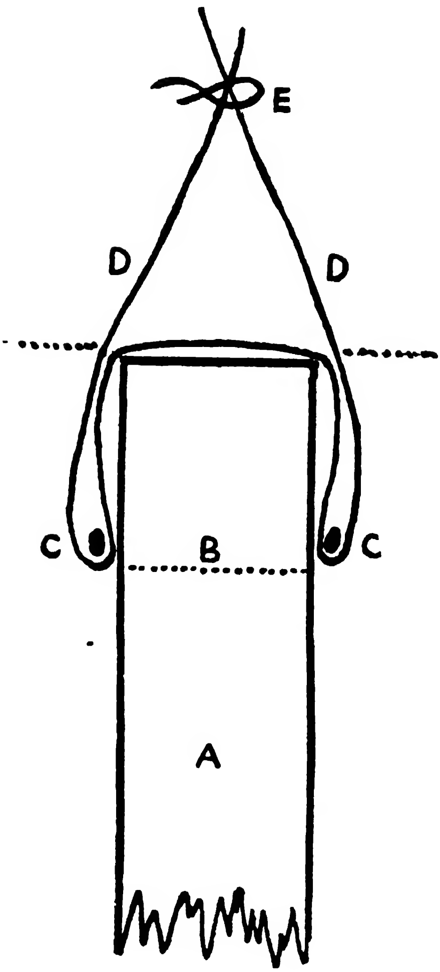


FIG. 5.—The making of banana-fibre 'pots': (*a*) Squared post; (*b*) The rim of the inverted pot; (*c*)(*c*) The first tie of twisted banana-fibre; (*d*)(*d*) The banana-fibre strips are all bent upwards over the tie; (*e*) The banana-fibre strips are temporarily tied together.

containers is never allowed to dry out. An attempt might well be made to pack a thin layer of strawy grass between the plants to cover the tops of the pots, especially when shade is reduced to harden off the young plants.

If the containers are such that they will decompose in the soil, the whole pot and seedling may be planted in a field vacancy without disturbing the roots. It is not wise to water pot plants when they are about to be planted in the field, lest the containers are already somewhat decomposed and fall away as they are handled, together with the wet soil.

THE MAKING OF BANANA-FIBRE POTS

The following sketches and Plate XXIII show how containers can be made from the strong, dry, outer sheaths of banana stems. According to the size of the post, they may be made large or small, and it is advisable to use a

squared post, so that the containers resemble deep square punnets. They can then be placed close together in nursery rows. A convenient size would be 7–8 in. deep and 4½–5 in. square. (*See* Fig. 4, 5 and 6).

THE MAKING OF POTTING BASKETS

Potting baskets are made of materials that are in use locally for basket ware. It is usual to dry them first, then moisten them to make them pliable, after which the six main supports about two feet long are laid like the spokes of a wheel and crossing at their centres. They are fixed by interweaving slightly thinner material to form the bottom of the basket about five inches in diameter. Afterwards the twelve ribs are bent upwards and the weaving is continued to the desired height. The last inch or two of each rib is bent over and tucked into the weave. (*See* Fig. 7(b)).

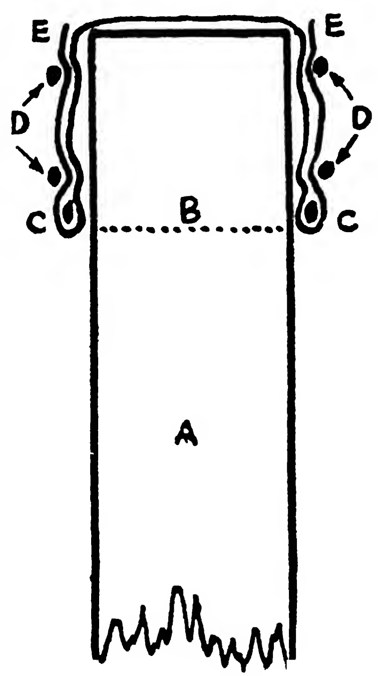


FIG. 6.—The making of banana-fibre 'pots': (*a*) Squared post; (*b*) The rim of the inverted pot; (*c*)(*c*) The first tie of twisted banana fibre; (*d*) (*d*) Two more surrounding ties of twisted banana fibre; (*e*)(*e*) The ends of the tough banana fibre strips are cut off level with a sharp knife, after which the finished pot is lifted off the post.

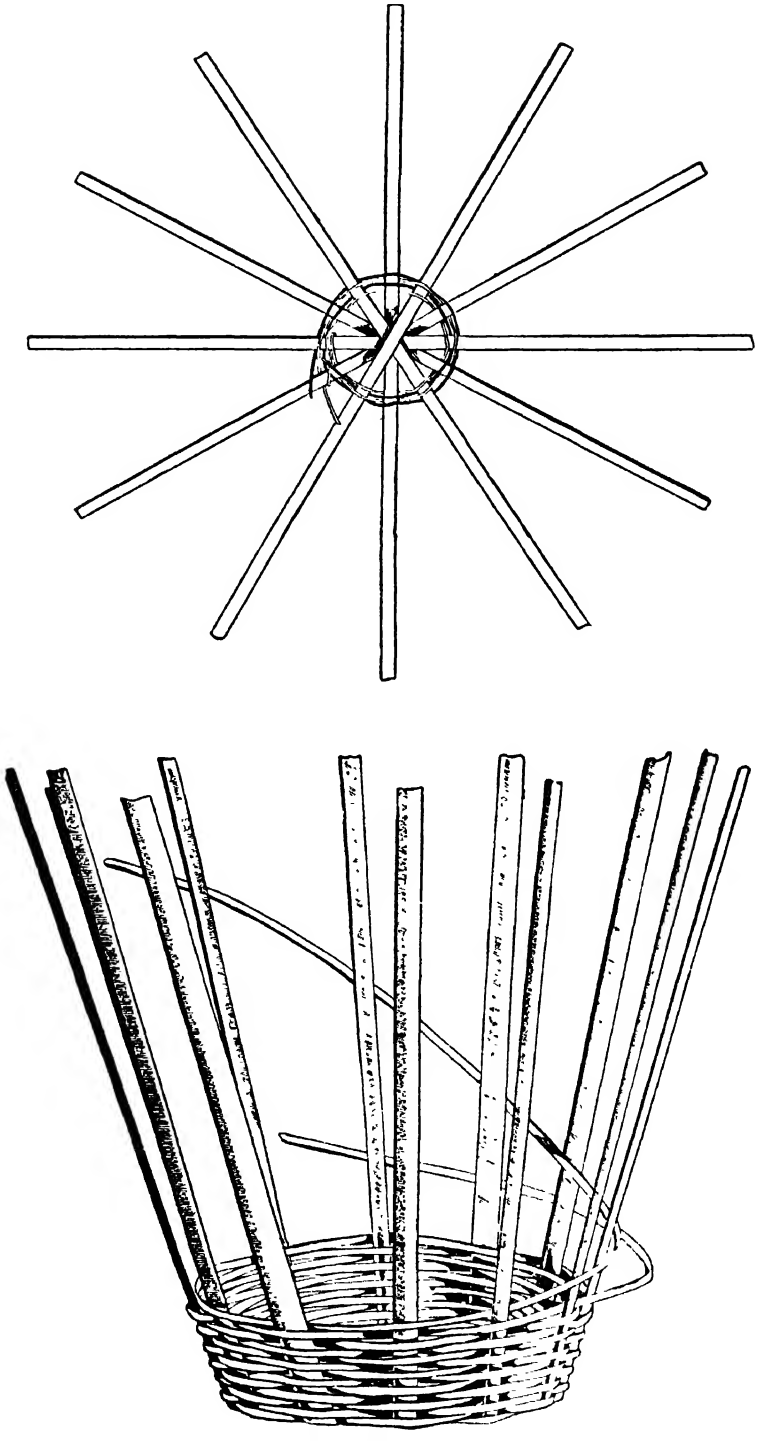


FIG. 7(a)—Potting Basket Construction
(By courtesy of the Commonwealth Bureau of Horticultural and Plantation Crops)

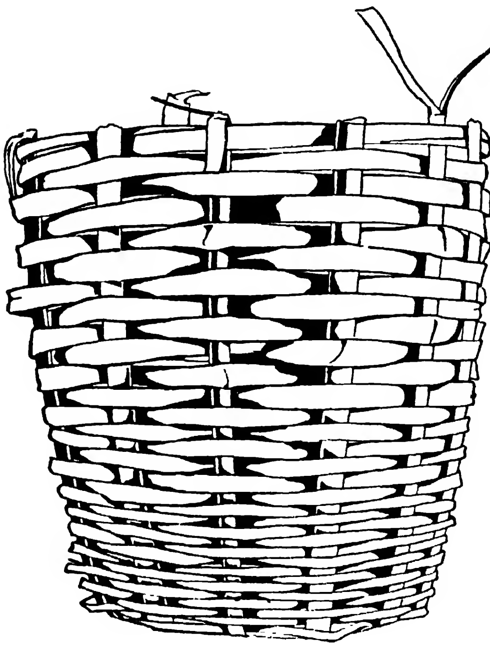


FIG. 7(b).—Potting Basket Construction
(*By courtesy of the Commonwealth Bureau of Horticultural and Plantation Crops*)

Chapter VII

PROPAGATION BY VEGETATIVE MEANS

The Different Methods applied to Coffee

With fruit trees of any kind there are several methods of vegetative propagation: (*a*) cuttings, (*b*) budding, (*c*) grafting, (*d*) layering, (*e*) marcottage, which is a form of layering. The last two cannot be used economically for coffee.

The economic species of coffee have two kinds of branching on each tree, i.e., vertical or upright growths (orthotropic) and horizontal laterals (plageotropic), and when a lateral has died back to an upright growth, it can be replaced only with great difficulty.

It is impossible to form a bush by budding or grafting lateral growth on to a cut-back seedling stock, because the scion would not grow upright. The dormant buds of upright growths are situated at points immediately below where the laterals spring from the main stem, and not above as in most other races of plants. If a vertical stem is topped, two new uprights will grow on either side from below the two top laterals.

If coffee is kept pruned to a single stem, new, unwanted uprights will constantly appear at the top of the bush, and also at times from different portions of the trunk, especially if the tree is in poor health. These unwanted vertical growths are called 'suckers', 'water shoots' or 'gormandizers'. If a vertical stem is bent and arched over, many vertical growths will grow out from the arched portion of the stem, and this habit is made use of in the Agobiada system of pruning. These may not truly be called 'suckers' or 'gormandizers' unless they are in excess. Similarly, when the uprights of trees trained to a multiple-stem system begin to bend over, vertical growths may again sprout from the upper bent portions of these stems, and if these also are unwanted, as is usually the case, they may alike be called suckers or gormandizers, since their vigorous growth is sapping the strength from the fruiting branches. The definition of these terms is necessary to avoid misunderstanding.

Clonal Propagation by Vegetative Means

In its genetic make-up a mother tree may have genes arranged so that they do not permit all the seedling progeny to grow to the same standard as their parent. A plant must be reproduced exactly and true to type if it is increased by vegetative means. By rooting cuttings of one tree, and increasing their numbers as time goes on, a field can be planted of one clone having all the same characters concerning, for example, vigour, disease and pest resistance, or high yield.

Not that this would be wise on a commercial scale. It is risky to depend upon one clone which may have hidden weaknesses that develop later, such as a peculiar susceptibility to a new disease. Hence, if clonal material is used, a mixture of clones developed from separately selected mother trees should be

By courtesy of the Royal Institute for the Tropics Amsterdam

(*a*) Nursery beds Kalisanen estate, East Java Grafted seedlings, most of which have paper covers

(*b*) Six-month-old grafts of 'Congusta' robusta hybrid in Bangelan, Java, on twelve-year-old stump of ordinary robusta. *Crotalaria* sp is inter-sown and the shade trees are *Leucaena glauca*

By courtesy of the Royal Institute for the Tropics Amsterdam

PLATE XXIV

By courtesy of the Kenya Information Service

Good sucker material for cuttings, Kenya

PLATE XXV

planted, and the more clones used, the safer it will be to adopt this procedure. Arabian coffee is self-fertile, but many a robusta tree is self-sterile and must have pollen from another clone or variety before it will set fruit.

Budding and grafting, or the raising of rooted cuttings in sufficient numbers, is far more tiresome, difficult and expensive than raising plants from seed. Research at Lyamungu has shown that provided a good strain of seed can be obtained from progeny-tested mother trees, very little advantage, if any, can be gained by vegetative reproduction, about which we still have much to learn. As stated, experimental tests over a long period of years have shown that there is no dependable significant difference in the yields of selected strains raised from cuttings, and those raised from good seed. A seedling at least has its own natural root system whereas a cutting has to develop one, more especially the vertical roots which delve downwards in search of moisture in the subsoil.

As for budding and grafting there is the union to be considered: where the microscopical tissues and fibres used by the plant for various purposes such as the transport to and fro of raw and manufactured nutrients, must all unite and sort themselves out. A hopeless tangle, or indeed dead tissue is left in the middle of the join over which the cambium cells must build new tissues in proper order. If a union is imperfect, or even if it is good, there may be internal hindrance to the flow of nutrients leading to unbalance. The roots may be starved or the leafage be thirsty, and when the tree is in full crop, exhaustion may follow. One often sees an old grafted tree with a trunk bulging over the old union (or vice versa) supported by a narrow rootstock exhibiting various degrees of incompatibility.

Reasons for Budding and Grafting

Budding or grafting must be done for a specific purpose, and unless there is such a purpose in view there is no reason to use these means of propagation at all. Deciduous fruit trees are budded or grafted on 'dwarfing' stocks to reduce the vigour of the crown, to obtain more fruit thereby at the expense of leafage and confine a vigorous grower to a branching habit from which the fruit can easily be gathered. A variety susceptible to nematodes may be grafted on to a rootstock which is resistant; in such a case the rootstock may even be of wild uncultivated origin, producing no fruit of commercial value. Furthermore, the budding or grafting of fruit trees such as apples and pears leads to earlier fruiting.

Sometimes it is very difficult to propagate a tree from cuttings on a commercial scale, and if the variety concerned has genetic characters which prohibit the production of viable seed, albeit the fruit is still excellent, as, for instance, in the case of the seedless orange, vegetative production becomes imperative. The rooting of cuttings from mature and tested *Hevea* rubber is not yet possible, hence the use of budding and clonal seed.

With regard to plantations of coffee, budding or grafting may well be applicable when the framework of a tree has been damaged by exhaustion or by some other cause. Where the laterals of a single-stemmed tree have died back, it might become possible to substitute new growth. It may be possible to prevent gaps in an old plantation by grafting, because such trees may fail otherwise to recover to a state of economic value. Gaps are hard to fill and the gaps which are usually found in old plantations are the chief causes of low

yields. Stumping to obtain new uprights is not always successful, for it is too ruthless and may lead to the death of the rootstock.

Top working may be employed to substitute a better variety and thus avoid the expense of uprooting an orchard and its shade trees and planting afresh, where the old orchard was begun with unselected stock. Top working is distinctly advisable, where, in a plantation raised from clonal and carefully selected seed, there is a small percentage of trees which prove unthrifty.

The most apt and necessary application of vegetative reproduction is found in research work, since it is vital to know that a whole field is of the same genetic structure and that every plant will respond in the same way to any one treatment. If one considers, for instance, a trial to determine which is the best pruning method, it would be unfair to count the yields of individuals, or of small plots or groups of trees if each tree varied in its inherited characters. Clonal work is absolutely necessary in regard to research of this kind, and the Lyamungu Research Station in Tanganyika was the first to mature fields of clonal stocks for experimental purposes.

Then, the rooted cutting comes into its own. When clonal work is tried with budded or grafted material, the influence of the stock upon the scion, or of the scion on the stock, becomes a disturbing feature. Influences of various kinds have indeed been found to occur with scions grafted on seedling stock, or on stocks belonging to different species of coffee. They have been shown to be considerable by Dutch workers in Java. To arrive at true clonal material, the scions of one selected tree must be grafted on rooted cuttings derived from only one other tree. There is no short cut, and the use of rooted cuttings is the only dependable method of obtaining clonal coffee material for research.

However, since cuttings must only be procured from vertical 'sucker' growths, and suckers are not obtainable from one selected mother tree in the numbers required, it was found advisable in the beginning at Lyamungu to graft the first suckers as scions on to nursery rootstocks. In such a manner can more vertical stems of the scion material be obtained quickly. These can be bent over and pegged down along the surface of the ground after the primaries have been pruned away so that more and more sucker growths may be produced, especially if the nursery stock is trained to grow multiple stems which are pegged down in all directions. Grafting can thus be used to multiply suckers to the number required to make a start, and material for cuttings can then be produced in such abundant supply that a batch of rooted cuttings of the same age may be procured for planting up the required experimental area.

This is the quickest way to start a supply of sufficient material for cuttings of the same age and origin for planting anywhere. While propagation is begun in this manner from several seasons of grafted growth, the earlier suckers which are produced in the nursery in excess are themselves rooted as cuttings and pruned to obtain layered multiple-stem growth in similar fashion. This will assist in increasing the ultimate supply until grafting for nursery purposes is no longer necessary. Afterwards the stock is kept going to provide successive batches of cuttings to extend the planted area block by block.

Using this method a planter could also obtain, in time, sufficient material from which to root cuttings to plant up an extensive area. A loss of time would be incurred in the beginning, and the whole business needs care and

skill which is difficult and expensive to apply to commercial planting. Moreover it would be necessary to propagate several clones to obtain a plantation wherein a number of such clones were safely mixed. It would be better to arrange for some central nursery on a co-operative basis to engage itself wholly on this work. It is understood that Lyamungu Experiment Station in Tanganyika has already issued a number of rooted cuttings of clonal material to planters in the Kilimanjaro region.

Budding Coffee

There is considerable literature dealing with the subject of vegetative reproduction, and some of the findings of research workers are contradictory. The earlier work on budding and grafting was done in Java, and historical data are obtainable from the writings of Ferwerda[8] and Cramer.[4] A warning is necessary regarding the determination of the species used and the names of the varieties mentioned in these early records. '*Coffea quillou*,' for instance, is merely a form of *Coffea canephora*. The 'Conuga' or 'Congusta' hybrid was created by crossing *Coffea congensis* with '*Coffea ugandae*'. Here again the latter is just a form of *Coffea canephora*, and several authorities suspect that *Coffea congensis* (*see* the chapter on the botany of coffee) is also a form of the same parent species. The 'Conuga' hybrid must therefore be treated as robusta coffee for the time being and as a varietal hybrid rather than a specific hybrid.

It is stated, for instance, that grafting was done on *Coffea liberica* to obtain nematode resistance, and much is said about the strength and form of rooting of the different species used as stocks. Unfortunately, on account of the confusion that has arisen in the herbaria of the world, little reliance can be placed on many of the determinations. There are many forms of Liberian coffee and those used as stocks may themselves have been hybrids before they, in turn, were hybridized in Java with Arabian or robusta coffees.

In fact, much of the information must be treated in a general sense, and a careful research with certified species and varieties needs repeating to confirm many of the earlier findings.

With regard to budding, one matter needs discussion in relation to the orthotropic and plagiotropic branching of coffee. Marshall[13] is emphatic in stating that buds inserted into lateral shoots will develop only lateral growth and throw out multiple shoots from the original bud, whereas lateral buds inserted in the main upright stems will produce normal upright growths. Grafts, he says, other than those of terminal shoots, do not develop a main stem, irrespective of where the scion is inserted.

Narasimhaswamy[16] states, concerning the well-known 'polarity' of coffee branching, that although experiments to induce a change in this habit had failed in the past, a few buds from lateral growths had developed sucker growths in more recent tests. In these the axillary bud at first produced a shoot which grew a normal lateral, but later, from below the axillary bud an accessory bud began to develop a vertical shoot, and this phenomenon was observed in eight cases out of seventeen.

The records of Marshall and Narasimhaswamy were questioned by someone signing himself T.V.P.[5] who stated that results of this type had not been reported by any other worker doing bud-grafts on coffee. Neither do the workers at the Lyamungu Experiment Station agree, because it is stated that

buds from laterals have consistently given lateral growth when inserted on upright or leader stocks.[9 19]

There may, of course, be rare cases when buds of lateral growths give rise to uprights, but the author never saw this happen in more than twenty years' close contact with coffee fields. It would seem that Marshall was mistaken and that lateral buds seldom if ever give rise to sucker growths on upright stems. It is also not at all easy to gain new laterals by inserting lateral buds on mature upright growths, mainly for the reason that the bark of old stems is too brittle to allow the successful insertion of either buds or side grafts. It would be better to graft a lateral scion on to the peg-like stump of an old lateral if it has not died back to the main stem.

Budding is not favoured by Marshall, who states that grafting gives better results with coffee, since the union of the stock and scion is much weaker when budding is done. It is a delicate operation, he states, and not to be recommended where large numbers of plants are to be worked. Budding was not favoured in Java, and though it was practised in the beginning at Lyamungu it is no longer used there to any great extent. At Lyamungu they had a good percentage of takes, but it is stated in the 1936 report that grafting was more successful, chiefly because the operation of budding is more delicate and native workers were not skilled. The buds and stocks appeared to join satisfactorily, and at the end of two-and-a-half to three years the unions were 'quite unnoticeable'.[19]

THE ACT OF BUDDING

According to Gilbert[19] budding can be performed with success at any time of the year with from 50 to 90 per cent takes. Gonzalez[11] states that though 95 per cent takes were procurable in the dry season, success was much less in the wet season. In accordance with general horticultural practice, budding is usually done a little while before the sap begins to rise, or during the height of the growing season, in which case one might expect the best time for budding coffee to be before the start of a new flush, or during the season of growth. One important fact in favour of budding is that if the first bud fails, another may be inserted on a different portion of the stock.

Webster[26 27 28] believes that the point of insertion of a bud on the stock is immaterial, but this view is not held in Tanganyika[19] where the most suitable height on seedling stock has proved to be about nine inches to a foot above ground level. Both authorities prefer shield budding, and the use of buds from upright growths, using the T or inverted ⊥ method of insertion.

Scion buds are usually taken from young wood. The bud is removed with a razor-sharp knife by a shallow slicing cut, which should begin ½ to 1 inch below the bud, pass under the bud, and end a ¼-inch above. If the knife is arrested before it quite reaches the surface of the bark at the finish of the cut, the bud may be removed by tearing, so that a small strip of bark in excess above the bud will make a convenient handle. This is cut off after the bud has been inserted. The shallow sliver of wood remaining attached to the back of the bud should be carefully removed before the bud is inserted. If the method of insertion used is the inverted T, then the bud must be cut from above, so that the knife slices it off in the reverse direction.

The most suitable type of bud appears to be one in which the 'eye' is just breaking, so that the actual bud is 'showing green', and it is usually possible

to tell if the bud has taken after the first two months. It begins to shoot three or four months after budding, and once it truly breaks then growth is rapid. The method used in Tanganyika has been to cut the top of the stock back a bit when the shoot breaks, and to prune it right back to the bud when the scion shoot is six inches to a foot long. Flowering and fruiting take place within two-and-a-half years after budding, according to the time of the year when budding is done. With regard to the upright growths of coffee it must be remembered that the buds in the axils of the leaves produce lateral and upright growths and it is the accessory bud, adjacent, but beneath the lateral one, which produces another upright.

Webster advises the use of buds from well-matured wood, of a greyish-brown in colour, from which the leaves have been removed two weeks in advance. The bud-shields should be cut 1½ inches long. He says the age of the stocks should not exceed two years, or the bark will be found too brittle.

In making the bud, as much of the wood as possible should be removed from the shield of bark, and every precaution be taken to prevent the buds drying out before insertion. Dormant 'eyes' do not break for a long while, and dormancy has been known to last for more than a year. Several authorities advise the bending over of the tops of the stock plants to assist the buds to break, or the scion shoots to grow, removing all the suckers which may arise from the stock during this process.

The usual method for the insertion of a shield bud is to cut the bark across the stem of the stock just below a node in wood of approximately the same age and appearance as that from which the bud was taken. A vertical cut is then made down the centre for a length of about one-and-a-quarter inches, thus forming a T. The bark on both sides of the vertical cut is then gently loosened and slightly raised so that the prepared bud can be slipped in at once, and positioned so that the eye is below the cross cut. The upper part of the shield above the eye is then cut off to correspond with the cross cut on the stock, care being taken to see that the back of the shield lies closely against the bared wood of the stock. The bud is then completely and immediately wrapped with tape or raffia and the whole covered with a cylinder of waxed paper. All cuts should be made with a razor-sharp knife. An unskilled worker will fumble and take too long, so the task is one for skilled and practised hands.

If the eyes are showing green it will probably be advantageous to arrange the ties so that the eye alone is not covered by the binding material. All ties should be loosened within about two months and retied so that the eye is exposed until the union has been made, taking care that the ties are never tight enough nor left in place long enough to restrict growth. (*See* Fig. 8.)

The brittle bark of older stems can sometimes be softened by pre-treatment. In dry weather the soil should be well watered. If soft soil can be mounded up, or boxed round the stock for a period of six weeks or more, and kept moist, then the bark may soften sufficiently to permit budding to take place. The bark is generally less brittle during wet growing seasons when the tissues are filled with sap.

Grafting Coffee

There may be unknown factors militating against the success of grafting—and also budding, for that matter. The chief of these is the incompatibility

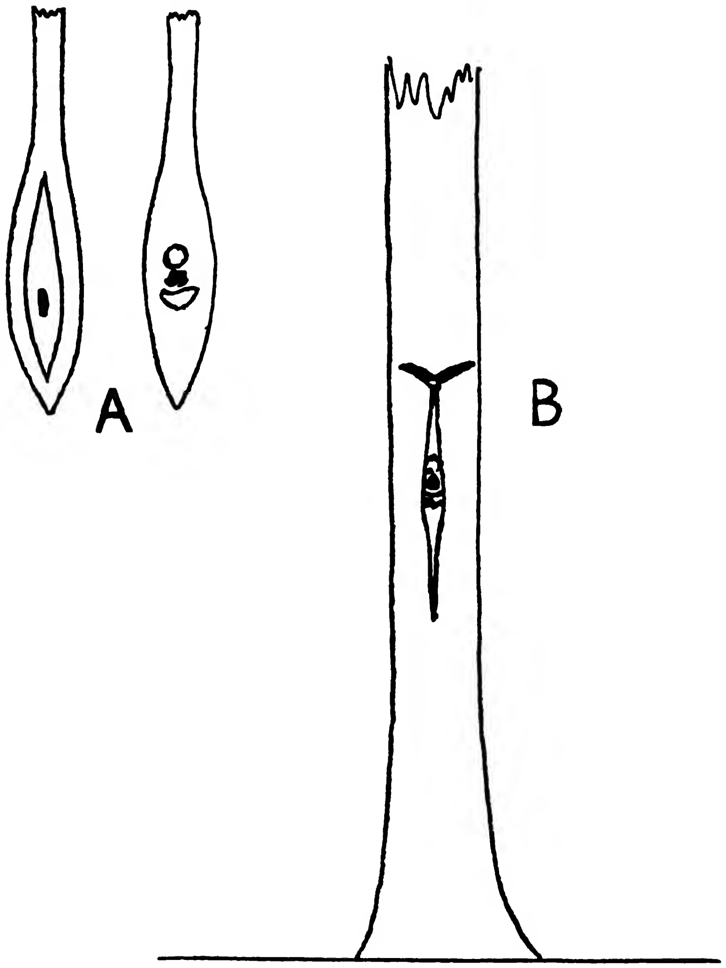
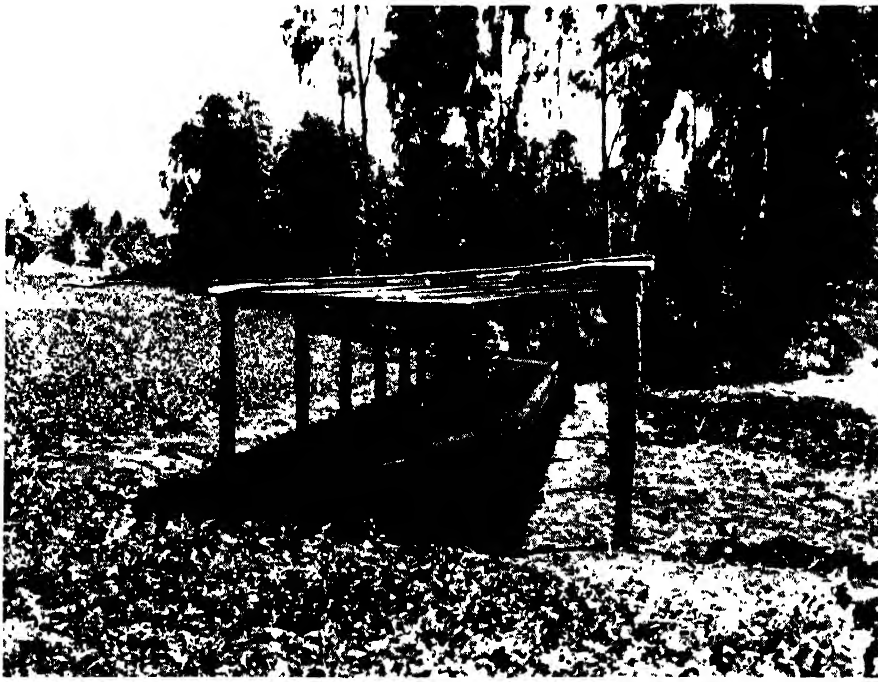


FIG. 8.—A: Bud shield back and front. *Back.* Showing sliver of wood which must be carefully removed. *Front.* The young lateral has been cut away. The orthotropic bud is in the centre and the leaf scar below. B: Stem of stock with 'T' cut. The bark has been carefully levered loose, the bud inserted, and the top ragged portion of the bud-shield cut off. It is now ready for tying.

often found between stock and scion. There are degrees of incompatibility between different species and varieties of coffee, and between individual trees of any species or variety when the material is not clonal. With luck compatibility will be present, the union will be perfect, and the tree will grow healthy and bear good crops as though it were on its own roots. In some cases union will be refused because incompatibility is complete. In most cases, a slight degree of incompatibility may exist but pass unnoticed, though this accounts for some of the failures in later life when the trees are bearing heavy crops. There may be yellowing of the leaves, die-back and exhaustion not accountable to any environmental influence.

Beyond this, there are the influences of the scion upon the stock, or the stock upon the scion, which in some instances are said to be startling. These influences may be beneficial, or evil, and it all goes to show that we should



By courtesy of the Kenya Information Office

(*a*) Single line of propagating bins, Kenya

(*b*) Syringing the bins of coffee cuttings, Kenya

By courtesy of the Kenya Information Office

PLATE XXVI

Coffee cuttings set in compost in a propagating bin, Kenya

PLATE XXVII

exercise care before we begin to use grafting or budding on a wholesale scale for commercial purposes, e.g., for top working an old estate of mixed seedling coffee with a new variety or kind of coffee.

In sound grafting practice, the degree of compatibility of stocks and scions, and the influence of one on the other, are known beforehand. This is so with many temperate fruits such as apples and pears, and with crops such as peaches and citrus fruits. A very small beginning has been made with coffee, because the influences and compatibilities of some clones are now known. In general, however, the reactions are unknown, or known only approximately, and the fact that there are so many forms of the different species of coffee, many of which may be natural hybrids, and the fact that the determinations are confused, make it clear that we have much to learn.

The influence of the scion or the stock, and the combination of the two, can affect the date of ripening of coffee; this may be quite different to that of the mother trees whence the scions were obtained.[3] This might allow the staggering of harvest and be very useful knowledge. Cramer says that some vigorous scions grafted on to vigorous stocks exhibit poor compatibility, whereas weakly scions on vigorous stocks may prove compatible and make a rapid growth. He states that the influence of the stock on the scion affects the success of grafting and that in many cases the scion itself seems to exercise unfavourable influences on the stock. Grafted trees may be more susceptible to disease and less drought-resistant. On account of influences and imperfect unions there will be a percentage of weak and tardy growers in most fields of grafted trees. According to Ferwerda[8] the various robusta coffees, their varietal hybrids, and the hybrids between Liberian and Arabian coffees all make good rootstocks for robusta clones.

Gillet[10] says, concerning top-working an old estate of Arabian coffee with a view to improving yields, that the characters of the existing trees must be studied. In most plantations the following will usually be found:

(*a*) The good, vigorous bush with good average yield.
(*b*) The good and healthy tree which gives a poor yield.
(*c*) The 'weedy' plant which may flower well in most years but is unable to carry the crop, so that there is heavy berry-fall and severe die-back.

The opportunity for grafting lies mostly with category (*b*), for the trees will be found to have a good root system, and the chances are that grafting will improve the yield.

It will be noticed that he gives no definite promise, and in regard to category (*c*) he says that this type of tree is almost invariably found to have a poor root system, so any attempt to improve matters by top-working is doomed to failure. 'These trees should be taken out.'

According to Gillet, therefore, top-working is not necessarily a means to prevent gaps occurring in established plantations.

The following information is given by Schweizer and Jacob.[22] Stock scion trials with seedling stocks of various kinds of coffee, and with robusta scions selected from several popular clones, showed differing incompatibility with non-robusta stocks. With robusta stock and scion combinations success was usual, though clonal preferences for particular seedling stocks were evident. It was shown that *Coffea dewevrei* (more likely a form of Liberian coffee), a vigorous eel-worm resistant coffee, was completely incompatible with robusta. Excelsa stocks from those which had especially been recommended gave

only a moderate performance, while Arabian stocks were only slightly better. Symptoms of incompatibility were yellowing of the leaves and failure to grow, shedding of the foliage in dry weather and die-back of the branch tips, also abnormal swelling at the union. The more pronounced the swelling, the greater was the accumulation of starch in the scion wood.

Several authorities[6] state that the influence of the scion on the stock is more potent than that of the stock on the scion. Ottolander in 1899 describes experiments with grafting Arabian coffee on Liberian rootstocks. The scions reduced the vigour of the root system and altered the colour of the roots. A liberica stock receiving an upright leader shoot developed a deeply penetrating tap root formation, whereas those grafted with laterals developed an abundance of lateral roots and only short tap roots. Moreover, weaker trees have been converted into vigorous growers by top-working them with scions from strong-growing varieties. If this is correct, then Gillet is wrong in stating that unthrifty trees with poorish root systems cannot be improved by top-working, though in many cases he might be proved right.

One could go on writing about isolated instances of various incompatibilities and other influences, but enough has been said to prove that grafting is not always as straightforward as might be thought. In general, incompatibilities are unlikely to be found noticeable, or to have any serious effects within the separate species of coffee. Robusta stocks are good for robusta scions, Arabian for Arabian and so on. A vigorous Arabian scion may indeed be found to refresh and invigorate a weakly rooting Arabian stock, as Gillet later reported after a visit to Southern India and Java.[6]

Interspecific, or interhybrid grafting may be found of economic use in future when more is known. Arabian coffee grafted on the shallower-rooting robusta species does not thrive in droughty weather or in drier areas, but there may be an advantage in having shallower roots in a very wet region. Conversely, excelsa rootstocks are drought-resistant and Liberian rootstocks nematode-resistant. By choosing clones, whose reactions when they are brought together are known, root systems may be selected of a kind best suited to any particular region; cropping may be arranged a little earlier or later thus extending the harvesting period. The ripening of any one clone will also be more even, though the chief value of grafting is for topworking and improving old-established coffee plantations.

THE ACT OF GRAFTING

At the coffee research station, Tanganyika, up to 90 per cent 'takes' have been obtained under nursery conditions with grafting by the cleft, saddle, side, notch and rind methods on Arabian seedling stock one and two years old.[6] Accounts are given in the Annual Reports of the Station, and it was found easier to uproot the seedlings, trim the roots, and, like patients taken to an operating table, do the grafting on a table. The grafted seedlings were then planted into frames where they were kept under controlled conditions of temperature, moisture, and shade, until the unions had been made, since a humid atmosphere accelerates callus formation and the subsequent union of the grafts. Once a good union had formed the plants were potted up, returned to the frames for a short while, and eventually placed outside to harden off, or planted in the nursery.

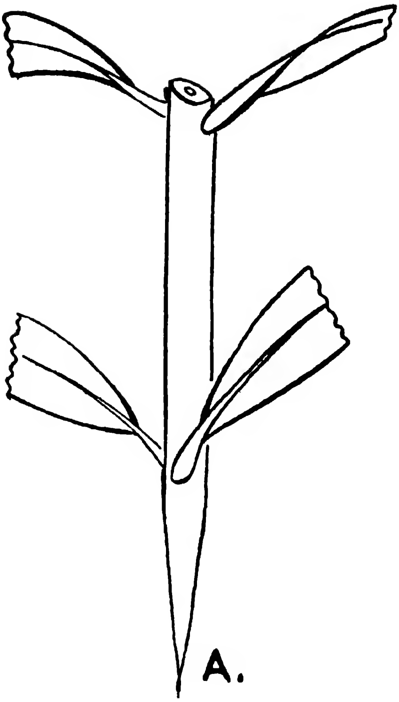
In a similar manner it has proved possible to graft rooted cuttings.

Slightly more difficult is the act of grafting or budding a cutting before it has rooted so that the union is made while the roots are forming. The percentage of 'takes' at Lyamungu was good, and a callus was quickly formed, making a rapid union between the stock and the scion. The great drawback has been the rooting of the hard-wood which is necessary to use for stocks. While rooting is slow, and may take up to six months or more, the shoots of the scions may grow rapidly in the propagating frames; they become elongated and chlorotic and often perish before the stocks have rooted. The technique used for rooting hard-wood cuttings must be improved before this method of grafting can be done on a large scale.

Most authorities have tested and neglected all the various methods of grafting young stock except cleft grafting, which was first used extensively for coffee in Java.[6] Ferwerda[8] states that a strongly sprouting sucker which is just becoming woody is chosen for scion material and cut into sections through the approximate centres of each internode. Two or three sections from the middle of the shoot yield suitable scions, but the two end pieces are less suitable. Wood about the thickness of a stout lead pencil is the best, though growth varies and this is only an approximate guide. The lower end of each section is cut to a wedge-shape with a razor-sharp knife, taking care that the cut surface is not soiled and the stock is about the same thickness as the scion. The stock is decapitated about 8 inches above soil level and split longitudinally for about 1½ inches. The wedge-shaped scion is then inserted into the slit so that the scion and stock fit exactly. The graft is then tied, but grafting wax is not used. For the first three or four weeks the grafts must be protected against drying out by means of inverted test-tubes, or tubes of waxed paper, and under the best conditions growth is so good that after six months the union can scarcely be detected. Gillet[9] says that the graft should be made on old brown wood on the rootstock and that the cut should be made just above an internode.

Marshall[14] advised that the top of the seedling stock should be cut off at, or just above, a node, where the bark and section of both stock and scion are of similar appearance. The stock, he says, should then be cut, not split, down the centre to a length of about 1½ to 2 inches. The scion is prepared by cutting off the leaves and shaping the lower end to form a wedge. McDonald[15] preferred seedling stocks no more than eighteen to twenty-four months old. He pointed out that the vertical cleft on the stock must be made across a node with a bud on either side, and the scion formed into a wedge beginning on either side of the bud. Webster[28] lays down that cleft-grafting is the only practicable method of grafting coffee. (*See* Fig. 9.)

In the Philippines a high percentage of success in cleft grafting was obtained all the year round, whereas in Mysore the most successful period was during the south-west Monsoon, when 90 per cent 'takes' were possible. In Java, where cleft-grafting is the only method used in commercial plantations, the best time is when the trees begin active growth after a period of rest, but before the sap-run becomes too free.[6] In Tanganyika, moisture at the roots has been found essential, and if grafting is done in the dry season, constant watering is necessary. At the best season, which is at the end of the dry season and at the beginning of the rains, the most successful method has been to use only a raffia tie and no grafting wax. All grafts should be protected with paper cones previously dipped in wax, and artificial shade is erected above the grafts. A planter in Java asserted that he was able to raise his percentage of 'takes'



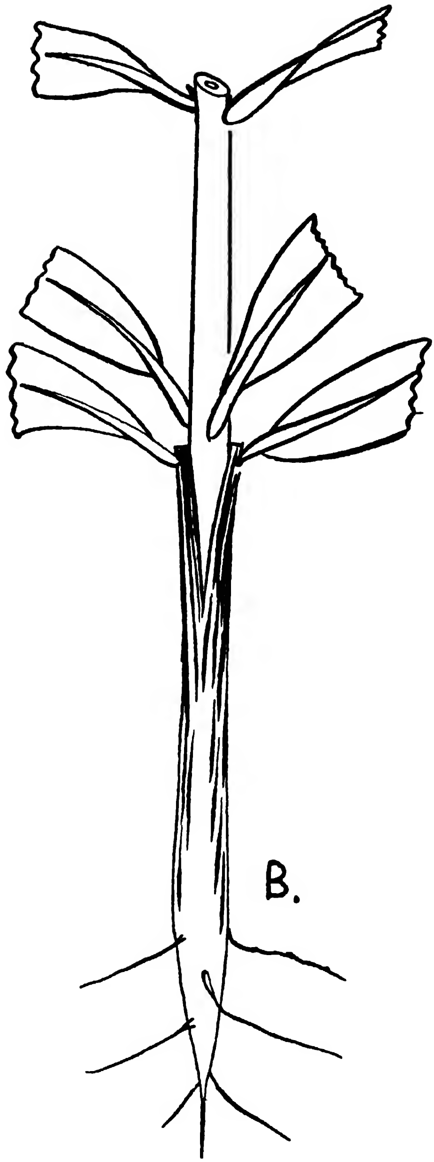


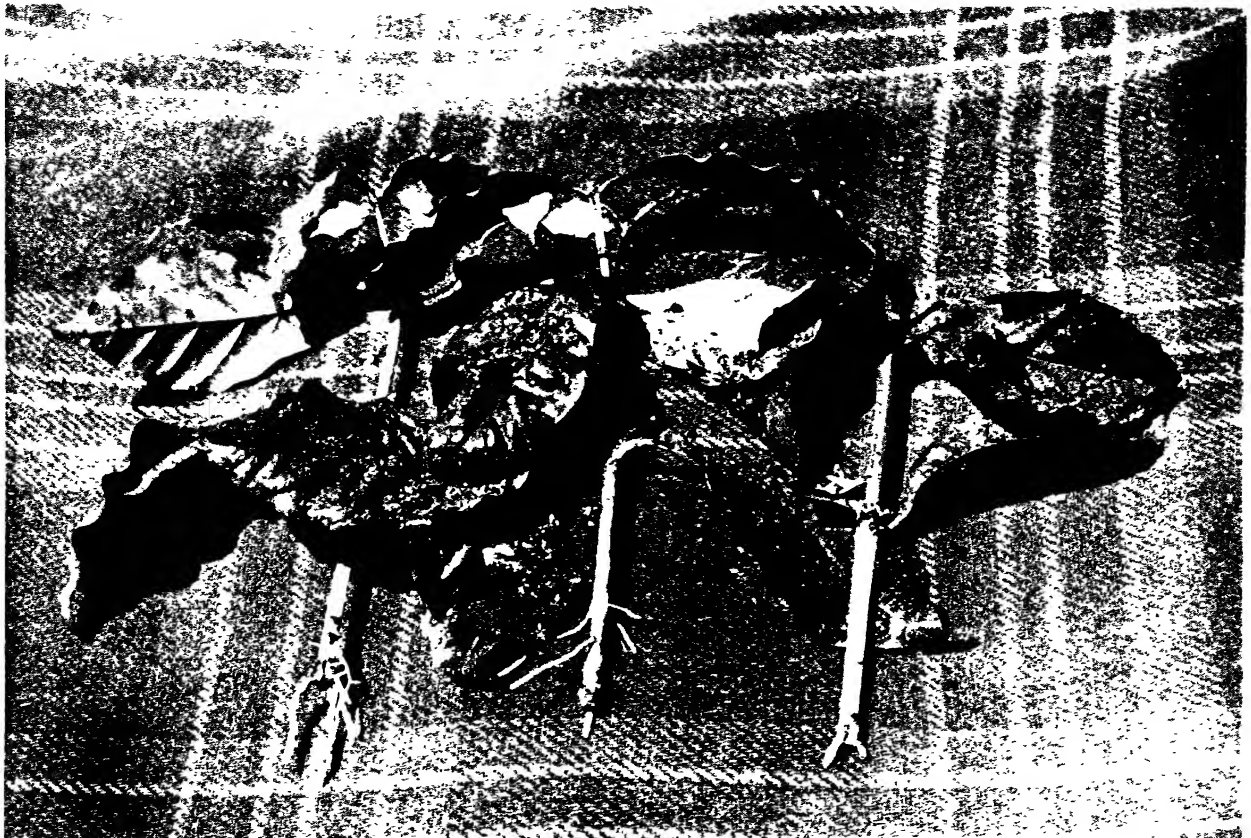
FIG. 9.—Wedge-Grafting.

A. Scion with wedge-shaped end ready for grafting.
B. Scion placed in a seedling stock ready for tying. Note position of the buds.

Note.—The leaves would normally be cut off or reduced.

20 per cent by allowing the lower leaves to remain on the stock plants after cleft-grafting had taken place.

The technique found most suitable at the Scott Agriculture Laboratories, Kenya, is as follows.[6] The stocks are planted in rows 2 ft. apart in the grafting nursery and the plants spaced 1 ft. apart in the rows. A 50 per cent shade is fixed overhead at a height of 6 ft. and cleft-grafting is carried out when the stocks have attained a diameter of $\frac{3}{8}$ in. to $\frac{5}{8}$ in. about 6 in. from the ground. The scion consists of one node and an internode, and it may be of hard-green, green and brown, or brown wood. Provided it is not soft or unripe, it may be in any stage of maturity without affecting the success of the



By courtesy of the Kenya Information Office

Rooted Arabian coffee cuttings, Kenya

PLATE XXVIII

By courtesy of East Africa Information Services

Seedling beds. Note loose laths laid on wire runners for adjusting shade, benches to carry them at end of bed and wide open pathways

PLATE XXIX

graft. Material from vertical growths is used and the grafts are tied with gunny twine and waxed with grafting wax. The scion and the union are then completely enclosed in a cylinder of waxed paper to prevent drying out, immediately the grafting has been done, and after two months this cover is removed. After a third month the tie is released, and a take of 80–90 per cent is expected when the conditions are warm and moist. Even with nursery care and more or less controlled conditions it is not possible to graft successfully all the year round in Kenya. Instead of using paper coverings, cylinders of banana leaf sheath have been used with success in Tanganyika.

TOP-WORKING

In temperate fruit orchards this means the pollarding back of all the main branches of a tree leaving three or four short stumps at the top of the main trunk. Several scions are then slipped beneath the bark of each stump in various ways so that new branches of a better variety are ultimately obtained. This is not so easy with coffee because the bark of the old stems is generally too brittle to work. Moreover, stumping an old tree gives the roots too great a shock.

To top-work single-stemmed coffee trees, all the primaries are cut away except a few at the top. These are left to give shade to the grafts and help feed the roots. Sucker growths will then shoot from the trunk and one at the base is selected for grafting while the others are all pinched away at an early age. If suckers do not grow readily from the base it may assist them to sprout if notches are cut in the trunk above where the dormant eyes are situated. Old coffee stems are usually too stiff to bend over to assist the dormant eyes to break, although some authorities talk of this as though it were an easy matter.

This basal sucker is then cleft-grafted when it has grown to sufficient size and maturity. Some may think it advisable to select and graft two suckers on each tree, and then, if both grafts take, the weaker one may be cut off leaving just the one strong sucker to grow up as a single-stemmed tree. Immediately the successful graft has been selected, the old top and the main trunk may be cut back carefully close to the base of the grafted sucker.

No matter how multiple-stemmed trees have been trained, the stems may be cut in rotation close to the base, and selected suckers springing from the stumps may be cleft-grafted in a similar fashion. In such a manner it might take three seasons to top work a three-stemmed tree, though there would not be such a loss of crop if at least one upright was fruiting all the while. Methods akin to these have been found the best for top-working in Kenya.[6] It takes about six months for new suckers to grow large enough to graft, and the grafts may be tied with gunny twine, waxed, and covered with waxed paper tubes. Grass tied round the old trunks and hanging down over the grafts provides extra shade if this is found needful. The paper tubes may be removed after two months, but though the grafts may still be alive, they have not necessarily formed a proper union and the ties should not be removed until another month has passed.

It has been found in Kenya that the success or failure of grafting depends on many factors—chiefly climatic, personal and physiological. The difference between 100 per cent take and complete failure may be brought about by only two months difference in the time of grafting. Every safeguard may be overthrown by an erratic seasonal rainfall when large-scale grafting is pursued.

Warm, moist conditions are best, and grafting may fail if the weather turns cold and wet, or hot and dry. Grafting should not be carried out when the sun is hot, so the task is best done during the cooler hours of the early morning or late afternoon.

Since old coffee trees are often out of rhythm regarding the 'on' and 'off' seasons of good harvests, individuals which look exhausted and unthrifty when the others are in heavy crop, may themselves bear well the following year while the majority are recuperating. This must be borne in mind when top-working unthrifty individuals, since no advantage may be gained. A tree must be proved a poor yielder over a period of years before top-working may be thought necessary. Published accounts of the percentages of poor yielders in commercial plantings have often been unwittingly exaggerated on this account.

Of course, it is possible to insert lateral scions into the stumps of laterals, though it would be tiresome to top-work and build up a tree in such a manner. Even with grafted suckers it is necessary to destroy all new suckers which arise from that part of the stock below the union, and with lateral grafting it would be necessary to see that only growths from the scions were permitted to exist. At Morogoro, Tanganyika Territory, cut-back branches of six-year-old excelsa trees were successfully rind- and side-grafted. Speed is considered essential for success in coffee grafting, and the stock should be cut back to just above a node. An internodal cut will result in the branch dying back to the node and the graft inserted in the internode will, of course, die with it.

The general health of a coffee tree, and particularly its carbohydrate status, would seem to influence the success of grafting. If a tree was suffering die-back after bearing a heavy crop it is unlikely that grafting would be successful, and it would probably be best to wait a while until the tree had recovered some strength. It has been suggested that branch grafts here and there may be found helpful among robusta clones to introduce a wider mixture of clones and thus assist in cross fertilization, especially if they are placed among the lower branches of trees where pollen is not so easily distributed.

In respect to top-working laterals, Marshall[14] advises bark-grafting. The branch of the stock plant is cut at or just above a node when the scion is ready for insertion. A slit is made longitudinally about two inches long and the bark of the peg-like stump lifted a little on each side of the slit to allow an easy insertion of the scion. The scion of much the same aged wood may be four to six inches long and carry from two to four buds. Its leaves are removed and a piece is sliced off one side of the butt end beginning just below a bud and finishing at the other side so that the cut face is about two inches long and perfectly flat throughout its length. The scion is then slipped under the raised bark of the stock, and then firmly tied in position and covered with grafting wax. The whole graft can then be covered with a waxed paper tube and kept shaded to prevent it drying out. The tie should not be removed until a good union has been made in about three months' time.

INARCHING

This, of course, means the joining of two growths while each is growing on its own roots. Afterwards, when union has taken place, the unwanted top of the stock plant is pruned away, and the root portion of the scion plant is

sacrificed. Thierry, in Martinique, first attempted inarching seedlings together soon after germination, and Dybowski working under glass at the L'Institut Colonial de Nogent-sur-Marne, simplified the operation with success by leaving both cotyledons in place and making a union below them. In this way were Arabian seedlings grafted on to nematode-resistant Liberian seedling stocks. The method has been used in Java of recent times and the plants are joined when possessing only the cotyledons.[6]

In Kenya inarching has been used as a means of top-working coffee in the western growing districts, where the rainfall is heavy. Blue mountain coffee proved somewhat resistant to coffee berry disease *Colletotrichum coffeanum*, and inarching proved of value in converting existing plantations of susceptible coffee to this variety. The ideal seedling for inarching on to a mature coffee tree is said to be one at least eighteen inches high with a healthy root system. A smooth section of the stem against which the seedling can be laid must be found, and earth is scraped from the centre of the row to cover the roots of the seedling. This is packed firmly so that the plant lies against the trunk of the rootstock at the place where it is to be inarched, and it is necessary to wait until the seedling exhibits new growth, before the job is done. The rootstock is then cut back to two feet from the ground leaving any laterals there may be on the lower portion to sustain the roots of the stock. After rubbing away any lichens or loose bark, a vertical cut three inches long is made in the stock, and horizontal cuts are made two inches long both top and bottom. The bark on either side of the vertical cut is lifted from the wood so that there are two flaps. Next a section of the seedling stem is sliced off to form a flat surface corresponding to the position where it is to rest on the stock. This is inserted under the flaps of bark, bringing the flat surfaces in close contact, and they may be held firmly in position by using strips of waxed cloth for binding. The roots of the seedlings are not removed when the unions have been made because they die off naturally, and a take of 80 per cent is considered reasonable provided the task is done at the warmest season of the year correlating with high humidity. Moreover, the ground must be moist.

ROOT-GRAFTING

Many kinds of grafting have been tried in various ways until at last success has resulted, but none of them has any advantage over those described, nor are they as simple and efficient as those mentioned in the foregoing. Attempts to graft roots failed at first until germinated robusta seedlings were used as scions, and six-inch long pieces of lateral roots of the same thickness as the scions were used.[2, 12] Complete seedlings were grafted at the hypocotyl by cleft-graft—seedlings with their cotyledons only and the shoots removed were grafted by side-graft—and hypocotyls with pieces of their tap-roots were grafted on to pieces of roots to ascertain whether a root on root graft gave a better union. The grafts were planted in a light soil in frames, the unions being above ground to prevent the decay of the scions. All united well, especially those which had been covered with glass tubes, and all the grafts formed tap roots from the pieces of lateral roots which were used as stocks. The procedure could not give more than academic interest, unless it were desired to graft seedlings of one species on to the roots of seedlings of a different species. The avoidance of rootstock suckers would also be achieved, for it must be

remembered with most grafts, care must be taken to see that sprouts do not grow afterwards from any part of the rootstock.

GRAFTING WAX

Recipes for grafting wax vary a great deal. The one given by Macmillan is: Crushed resin 4 parts by weight, beeswax 2 parts, tallow 1 part. W. T. Pope's recipe anent the Hawaii Agricultural Experimental Station Bulletin No. 59 of 1929 is selected by the authors of Technical Communication No. 13 of the Commonwealth Bureau of Horticulture and Plantation Crops. It occurs in his article *The Macadamia Nut in Hawaii*, and the materials required are by weight 4 parts resin, 8 parts beeswax and tallow 1 part.

The tallow is melted in a pot over a slow fire and then the beeswax is added. When the mixture begins to boil, the resin must be mixed in gradually, stirring continuously until it melts. After boiling the melted mixture for five minutes, it is strained through cheese cloth into a large container of cold water, and when cool the wax is worked with the hands until it is tough and doughy. Thorough cooling is important to prevent the forming of lumps, and though kneading may be difficult at first, it becomes easier after a while. If the hands are slightly greased with tallow the wax will not adhere, and as soon as it assumes a creamy, silken colour, it may be worked into rolls about 2 in. diameter and 5 in. in length and wrapped in waxed paper. The grafting wax is then ready for immediate use, or it may be stored. A small amount of tallow may be kneaded into the rolls to soften them if they become hard.

TIES

Grafting tape may be made by dipping plain cotton tape into hot beeswax to which a little antiseptic such as creosote has been added.[6] The tape is cut into lengths of ten or twelve inches and stored until required, after which the lengths may be drawn through the fingers to make them adhesive. Kenya authorities find gunny twine quite sufficient for tying grafts and in Tanganyika plain raffia is preferred.

GRAFT COVERS

A cover is necessary in the tropics to prevent grafts drying out, especially when wax has not been applied to the union. Various covers have been used, including glass tubes, waxed paper, sections of banana leaf sheaths, sphagnum moss and split bamboo. Test tubes may suffice for glass tubes, in which case shading is necessary. Waxed paper is made into cylinders which should extend from above the tip of the scion to below the union, and they can be filled with moist moss, sawdust, or fibre, if this is thought desirable. In Java red paper has been found to give better results. Banana leaf sheaths should be changed at least once, because they contract, and some dislike them because they harbour insects. Sphagnum moss bound round the join is tiresome because it must be kept moist, and split bamboos are not always easy to tie in position without making them too tight.

PROPAGATION BY CUTTINGS

Among the advantages claimed by Dutch authorities for grafting are (*a*)

uniformity in growth habit and quality of the ultimate product, (*b*) less variability in yields, (*c*) a more defined ripening period, (*d*) the ability to perpetuate a desirable variety and form a clone, (*e*) the possibility of using different rootstocks for various purposes, (*f*) the power to transform a poor orchard into a better one by top working, (*g*) the possibility of altering the time of ripening. All these benefits derived from grafting except (*e*) and (f) may also be conferred by using cuttings, and even (*e*) may be obtained, up to a point, by using clones with different root systems.

The disadvantages of grafting are (*a*) the difficulty of finding and raising a suitable stock, (*b*) incompatibilities between scions and stocks, (*c*) the influence of the scion on the stock or vice versa, (*d*) the occurrence of a percentage of weak and tardy growers, (*e*) extra skill and cost. At least two of these cogent disadvantages can be avoided by using cuttings, so that in general, the vegetative propagation of coffee by cuttings is overwhelmingly superior to grafting for most purposes.

One question to answer for commercial planting is whether a plantation raised from carefully selected progeny-tested seed would not be more simply and more economically obtained and just as good as one planted with rooted cuttings of tested clones. The author is of the opinion that the odd unthrifty bush will be found in every plantation no matter what method of propagation is used, and the unthrifty bush among those derived from grafts or rooted cuttings is more likely to be caused by influences which top-working would not cure. In a field grown from selected seed there are opportunities given in the nursery and during the early years in the field to rogue out and replace plants not true to type, or poor growers caused by some planting accident. There will still be time to plant supplies, and any tree that proves a poor yielder in after-life should be healthy enough to be improved by top-working.

On the other hand, in any country where selected and progeny-tested seed is unobtainable, it would doubtless be better to plant rooted cuttings from selected mother trees, working the material up to a sufficient quantity in the nursery, and using a mixture of clones. Care in these matters, and the use of either of these methods must be substituted for the irresponsible practices of the past, if it is desired to raise the average annual yield of clean coffee per acre from a mere $3\frac{1}{2}$ cwt. up to 10 cwt. and more.

At one time it was thought that cuttings would not make proper tap roots, and much breath has been wasted among planters by arguing the pros and cons of this matter, some saying that all coffee plants developed tap roots and must have them for healthy growth, and others saying that coffee trees did not normally develop tap roots and never needed them. In fact, it seems to depend on the variety, the soil, and the environment as to whether a coffee tree makes a pronounced tap root or not. If it wants to it will, and though most of its roots lie in the surface soil it has been shown that vertical moisture-seeking roots are often sent down to considerable depths from the laterals. Lateral roots will make tap roots, and cuttings will develop tap roots in time as easily as will seedlings.

The great advantage of using cuttings is uniformity, and the fact that a tree of proved performance can be propagated forthwith without the variability given by seed even when it is progeny-tested. This is of great importance when, for instance, disease resistance is one of the chief characters concerned. The only disadvantages are the lack of material and time lost while this is

being increased in the nursery; also that rooted cuttings are more difficult and much more expensive to raise.

Cuttings grow on their own roots, so there are no incompatibilities or unknown influences to be considered, and since seedling material tends to vary in its form of rooting, just as it varies in its growth above ground, good yielding clones with differing rooting systems may be chosen to suit different soils and environments. Strong roots may be required for stiff soils and deep roots for the drier regions, whereas a surface-rooting type would thrive better in a region of heavy rainfall. One need not graft on to other species to gain these differences in the rooting system. Moreover, it is just as easy to develop a single-stemmed tree, or a multiple-stemmed tree from a rooted cutting, as it is from a seedling.

TAKING AND ROOTING CUTTINGS

Research work in the rooting of coffee cuttings and preparing them of a kind and of a number for economic planting in the field, has been carried out since the early nineteen-thirties at Lyamungu and at the Scott Agricultural Laboratories, Kenya, and these are the principal authorities whence most of our information has been obtained. It has entailed a study of the best kind of material, methods of obtaining such material in quantity in the least possible time, the best rooting media, the best humidity, moisture supply, and temperatures, the best method of preparing the cuttings and of hardening them off afterwards for planting in the field. The rooting of the cuttings has been comparatively easy, and the main problem has been concerned with avoiding the death of the cuttings after they have been potted up, or during the hardening-off process in preparation for planting.

HARD-WOOD CUTTINGS

It will be remembered that the natives of Uganda used to propagate their robusta trees to obtain seeds for chewing by using quite large pieces of old upright growths which they rooted by bending them in the form of arches and inserting both ends in the ground. Though it has been possible to root hard-wood cuttings of Arabian coffee in Tanganyika up to 50 per cent, this percentage is lower, the time required is longer and the percentage loss on transplanting is higher than when soft-wood cuttings are used. Research stations in Kenya and India report similar results, and the general conclusion is that soft-wooded material is by far the best.

Portères[18] reports that at Bingerville on the Ivory Coast, experiments were carried out with seventeen varieties and kinds of coffee in the short dry season, August 1934. The cuttings were eight inches long and half to three-quarters of an inch thick. The lower ends were cut on the slant and the upper ends were waxed, and they were planted upright in a light sandy soil, cultivated to a depth of six inches and mulched with dry bamboo leaves. Waterings were given daily for a week and thereafter every three days, the results being recorded in the following November. A Liberian variety from Java was the most successful with 80 per cent rooted, but a local variety gave only 28 per cent. Robusta coffee from different districts varied in the number rooting from 22 to 67 per cent, the local Arabian gave 7 per cent, *Coffea stenophylla* 13 per cent, and *Coffea excelsa* only 1 per cent. On other occasions hard-wood

cuttings of robusta were in transit for five days and then rooted to the extent of 75 per cent. A method frequently used by the natives in at least one district of the Ivory Coast is to plant hard-wood cuttings of robusta 4–5 feet long and 3 inches thick in groups of three. It is usual for 80 per cent of the groups to have one or more of the cuttings successfully establishing themselves as trees.

From all accounts it would seem easier to root large hard-wood cuttings of robusta and Liberian trees than any other species of coffee, provided the environmental conditions are satisfactory.

SOFT-WOOD CUTTINGS (ARABIAN COFFEE)

Soft-wood cuttings of the best kind are obtained from the tips of leader and sucker growths of unshaded plants. They should be four to six inches long with short, round internodes providing three or four nodes. Overdrawn and shaded suckers with long internodes and flattened stems should be avoided, and care should be taken to select healthy material with no disease spots on the leaves. The cuttings should be carried and handled with care to avoid bruising any of the leaves and tender shoots.

The Annual Reports of Lyamungu from 1948 onwards contain the results of a number of experiments of which the first concerned a comparison of the rooting potential of cuttings derived from the field, and those from nursery material of the same clone. The cuttings from the nursery gave exactly double the number rooting within a given time, and it was said that the condition of the cuttings from the trees in the field, occasioned by heavier shade, was probably the main factor responsible for the poorer rooting response.

The next experiment set out to find what happened when the leaves of the cuttings were trimmed or untrimmed, since it is generally accepted in regard to soft-wood cuttings of evergreen plants that as much leafage as possible should be retained. In practice, the basal pair of leaves has been removed at Lyamungu and the remainder trimmed to save space in the propagating frames. The trimmed cuttings gave a rooting percentage of 68·1 as against 42·8 for the untrimmed in a whole series of trials. These experiments may not be conclusive, because the findings might well be altered by a wider spacing for the untrimmed cuttings, by a different rooting medium, and by differences in the way the humidity and moisture were controlled. The spacing of cuttings is, of course, largely a question of economy.

Early experiments tended to show that it did not matter very much where or how the basal cut was made, and a horizontal or semi-spherical cut just below a node was employed as routine practice. In 1948 four treatments were tried, viz.:

A. Internode cut wedge-shaped with top of cut at the node and point of severance internodal.
B. Internode cut at a slant with top of cut at the node and point of severance internodal.
C. Horizontal cut just below a node (control).
D. Horizontal cut through the internode.

After twenty-four weeks the results were summarized as in the following table.

Treatment	*Percentage rooted*	*Average No. of weeks to root*
A.	68	14·24
B.	66	19·39
C.	46	17·39
D.	68	16·59

There appeared to be a distinct advantage in using the internodal position as the point of severance. Later, a series of new experiments was carried out which proved that a cut in the centre of the internode, and the internode split to the node above gave the highest percentage of rooting in the quickest time, i.e. 89·4 per cent rooted in 16·6 weeks.

Next it was shown that clones built up from selected mother trees varied considerably in the time they took to root, and as the experiments proceeded it became all the more apparent that the longer cuttings took to root, the greater were the number of deaths after potting and during the hardening-off process. A graph in the 1948 report shows that deaths were insignificant when cuttings rooted within four months, and even after six months the percentage was not too bad. Among cuttings rooting after six months the percentage of deaths rose steeply to 30 and 40 per cent, and it is not considered worth while to keep cuttings in the frames longer than ten months. The reason for the deaths is that by the time the slow cuttings have rooted they have lost most of their leaves except for small bunches at their tips, thus they are in a state of extreme weakness and unable to stand a transfer. For these reasons, the inherited character of easy and early rooting is required when selecting a mother tree for vegetative reproduction by cuttings.

Preliminary tests indicated that if cuttings were given 12·80 sq. in. of space rather than 6·40 sq. in., the rooting percentage was increased by 19·7 per cent and the number of weeks taken to root decreased from 18·2 to 16·8 per cent.

A reduction in the variation of temperatures by two or three degrees with the minimum at 16·0° C. and the maximum at 25·6° C. was obtained by a constant stream of water running over the glass covers of the frames. This, however, depressed the percentage of rooting, but reduced the time taken to make roots by nearly two weeks. It is probable that a higher minimum temperature with less variation, together with high humidity, would have given still better results. Maximum temperatures should never be high and experience for a number of years on Kilimanjaro Mountain has shown that the percentage rooting is much greater during the cooler months of the year.

Light is of the utmost importance, and should be the maximum possible without causing the temperature in the frames to rise; this will be seen by the results of other authorities.

Young and leafy cuttings are generally easier to root in the tropics because the scanty food reserves in the tissues are all the while being increased by the process of photosynthesis within the leaves, and they produce auxins which are root-promoting. It is necessary to aim at keeping the leaves fresh, and preventing the loss of them while the callus of a cutting is being formed. The problem in the tropics lies in controlling and lowering temperatures to enable

the freshness and turgidity of the young leaves to be maintained. High temperatures are, of course, engendered by strong sunshine, so that shade becomes necessary.

The shade must be of the right kind and density, for if there is too much then photosynthesis may be curtailed and the leaves fall, or if there is too little then the temperature rises and the leaves may wilt. With cuttings that are difficult to root, this question of shade is often very finely balanced, and some species are more tolerant of shade than others. The correct moisture balance is again important and to control this it is best to keep the cuttings in a saturated atmosphere, i.e., 90 per cent humidity, with very little and only occasional ventilation. At the same time, the medium in which the cuttings are being grown must not be waterlogged. This is overcome by providing a medium of coarse sand alone, or a very sandy mixture well-drained below, which, though constantly wetted, has large enough air spaces between the particles to prevent waterlogging.

A form of propagator where controls can be exercised to obtain exacting conditions for prolonged periods is essential for material such as coffee that will not root easily. Even material that will root easily in the open will respond more readily and quickly in an efficient propagator. In climates where the mid-day temperatures are high, it is sometimes necessary to have fixed spray nozzles within the bins to give a constant mist spray during most of the day, and to arrange for continuous evaporation on the outside of the frame covers to cool down the temperature.

THE TRINIDAD PROPAGATOR

The methods in Trinidad have gained world-wide renown, and the kind of propagator used there is a garden frame with walls made of concrete. The back may be 3 ft. high from ground level, the front 2 ft. 10 in. high and the width 2 ft. 6 in. Such a frame may be separated into sections or 'bins', each 3 ft. long, with a separate sloping glass-framed top to each bin, either hinged or sliding, and fitted with handle-grips. For economy and convenience the frames may be placed back to back. Drainage vents are arranged at the bottom, and the bins are filled with 10 in. thick layers of large stones, then 6 in. of fine gravel topped with 6 in. of coarse sand or whatever compost mixture is found best. This will bring the surface of the beds within the frames to within 1 ft. of the lids. With coarse sand it is impossible to give too much water, and the aim should be at over-watering rather than letting the sand start to dry out. (*See* Fig. 10.)

The glass lids are usually covered with a double layer of cheese cloth which is kept wet during daylight, for this will cool the air in the interior of the bins by as much as 5–6° C. A maximum temperature of 28° C. is reached in the sand bed in Trinidad in the late afternoon, and a minimum of about 26° C. in the morning about 7 a.m., despite the canopy which is arranged over the frames.

A canopy of calico stretched on wires has been found best, arranged high enough to give head-room and projecting well beyond the frames on all sides. This gives just the right kind of shade, and to prevent the necessity of having side curtains along the whole length of the frames it is better to construct them east and west. At Lyamungu the canopy used is of hessian, and it will be noted that the minimum temperature is much lower—probably too low.

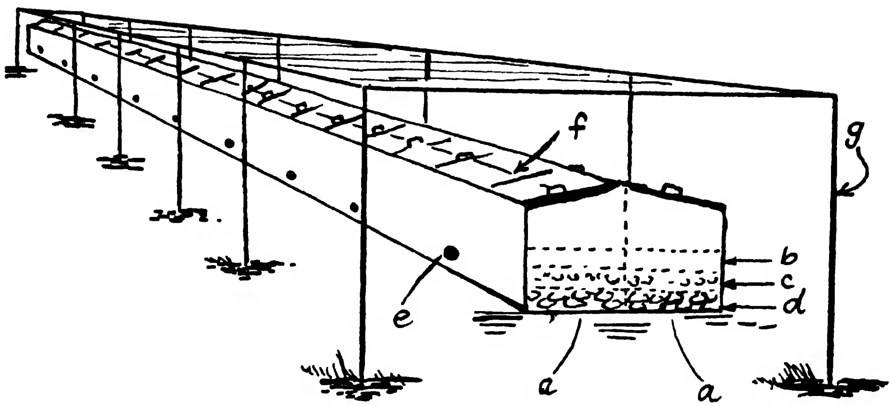


FIG. 10.—The Trinidad Propagator.

(*a*) Separate bins back to back.
(*b*) Six inches of coarse calcareous sand.
(*c*) Six-inch layer of fine gravel.
(*d*) Ten-inch layer of stones.
(*e*) Drainage vent to each bin.
(*f*) Removable lids with handles.
(*g*) Permanent frame for canopy of calico.

(*By courtesy of the British Trade Journal and Export World.*)

Cuttings should never wilt and the aim should be at preventing leaf-fall at all costs.

PRACTICE IN KENYA AND TANGANYIKA WITH ARABIAN COFFEE

After a great number of tests it was found that in Kenya and Tanganyika a rooting medium of 50 per cent peat moss and 50 per cent coarse sand was outstandingly successful. Many efforts have been made to find other materials to substitute for the rather expensive peat moss without real success, and vermiculite mixtures did not prove any better than sand. The following table drawn from the Lyamungu 1949 report is helpful.

PERCENTAGE NUMBER OF CUTTINGS ROOTED

Materials	*Mixed with coarse sand*				
	3 : 1 1.	2 : 1 2.	1 : 1 3.	1 : 2 4.	*Mean*
Wild date palm fibre—1. ...	72·0	87 4	93 4	92·0	86·2
Coconut fibre—2.	87·4	86·0	72·6	85·4	82·8
Peat Moss—3.	91·4	84 0	91·4	93·4	90·0
Coffee Parchment—4. ...	45·4	58·6	52·6	59 4	54·0

The first two materials gave an average rooting time of 14·8 weeks, the third, i.e., the peat moss mixtures, took an average of 15·4 weeks, and the fourth treatment 18·8 weeks. By 1950 it had been found possible to root 81·59

per cent of the cuttings set in the frames within a period of six months, and of these only 8·32 per cent failed to survive, i.e., 78 per cent of the total cuttings planted, rooted and reached the planting-out stage. To avoid damping off and decay in the propagator caused by *Rhizoctonia* disease, the treatment of all rooting media by Cheshunt compound has become routine practice.

(Cheshunt compound is made by mixing 4 oz. of Copper Sulphate with 22 oz. Ammonium Carbonate, and adding the mixture to 50 gallons of water.)

In Kenya the propagating frames have been designed to try and overcome as far as is possible the diurnal temperature fluctuation which is about 17° C. Bottom heat is supplied by two soil-heating cables originally controlled by thermostats, but as these did not prove satisfactory owing to excessive lag in switching on and off, and to corrosion, the temperature was later controlled by hand switches and maintained at about 24° C. Only the terminal growths are made into cuttings and the terminal buds are always left on with as much leaf as possible. The propagators are syringed once or twice daily and this is found sufficient to keep up the humidity of the air and the rooting medium. All the cuttings are treated with root-producing hormones before being inserted.

Concerning treatment with coloured light by using coloured glass, or coloured cellophane, and in comparison with ordinary daylight, yellow light has proved the best, and rooting was significantly assisted. Red light seemed definitely harmful, and whereas blue kept the cuttings alive, none of them rooted. The growth of an indicator plant placed in the treatments along with the Arabian coffee cuttings was 2 in. in daylight, 4 in. in red light, 10 in. in blue and 14 in. in yellow light within the time given.

In view of the success with single-node cuttings of both tea and cocoa elsewhere, a trial was made at Lyamungu to compare single-node stem cuttings of Arabian coffee with tip cuttings and with normal soft-wood cuttings. They were, of course, placed in a propagating bin. The normal soft-wood cuttings rooted 98 per cent, the tips 81 per cent, and soft-wood single-node cuttings 83·5 per cent. Single-node cuttings which were semi-hard at their bases gave only 61 per cent.

EXPERIENCE IN JAVA

Robusta coffee cuttings have been regularly rooted in Java, according to Roelofsen[6], by the methods used in Tanganyika. The muslin material covering the frames is kept moist by the leakage of water through perforations in bamboo pipes running just above the backs of the frames. The pipes are fed from drums into which water is pumped as required. This reduces the temperatures in the frames from 35° C. to 29° C., making all the difference between life and death for the cuttings, even though robusta coffee is considered to be tolerant of higher temperatures. The cuttings are syringed twice daily and the muslin covers to the glass are used only on sunny days from 8 a.m. to 3 p.m. A canopy of strips of bamboo is placed some seven feet high, to permit a quarter of the available sunlight to filter through. The essentials of success are said to be plenty of evenly-diffused light with cool temperatures, and the cuttings are lifted for examination after two months; those that have rooted are planted in basket pots, kept under glass for another month and then stood in the shade. In the wet season the extra month under glass is

dispensed with. A reduction in the rooting percentages takes place in the rainy season and this is attributed entirely to the reduced light, apart from *Rhizoctonia* attack which is then troublesome.[6]

RECENT INDIAN WORK

Efforts have been made in wet and humid months to root leafy cuttings in sand beds in the open, protected from direct sunlight by adjustable overhead screens of hessian. Single- and double-noded cuttings of robusta coffee were first used. In single-noded cuttings the top cut was made about half an inch above the node and the lower one about four inches below the node, so the material must have been long jointed. In double-noded cuttings the lower cut was through the node while the upper cut was half an inch above the top node.

The test showed that about 50 per cent of the single-noded cuttings rooted and they were assisted by hormones of which phenyl-acetic acid and cows' urine extract were the best.

A rather more extensive test under similar conditions was carried out with nodal cuttings of Arabian coffee in the following year. In this case the control cuttings which were not treated with hormones gave a significantly higher percentage of rooting. A test with various dilutions of hormones in propagators gave low rooting percentages in favour of Indole butyric acid and urine extract.[24] Indian workers seem very much in favour of using cows' urine extract, and the method of making this is given by Pattabhiraman and Gopalakrishnan.[17]

THE USE OF ROOT-PROMOTING HORMONES

According to Fernie[7] the cuttings that die, normally do so during the first three to six weeks. Callus formation usually begins about three weeks after the cuttings have been inserted in their rooting medium, and a complete ring of callus may be expected in five to six weeks. It is not until then that root initials are apparent, so anything that will help to hasten rooting should be adopted.

A useful experiment was carried out at Lyamungu in 1950 to discover if hormone root-promoting substances would increase the rooting percentage and decrease the time taken to root. Cuttings of Arabian coffee were used with the rooting technique that had been found the best hitherto, and alpha-naphthalene-acetic acid was dissolved in 50 per cent ethyl alcohol and used at the following strengths:

A. 1,000 parts per million.
B. 500 ,, ,, ,,
C. 250 ,, ,, ,,
D. Control. No treatment.

The concentrated dip method of application was used and the experiment was laid out in the propagating frames in four blocks arranged at random, each block having four plots of fifty cuttings each. Each block contained twenty-five cuttings each of two clones N. 29 and N. 71, and the duration of the experiment was twenty-four weeks from the date of setting.

PERCENTAGE ROOTED

Clone	*A.*	*B.*	*C.*	*D.*
N.29	95·0	94·0	93·0	89·0
N.71	90·0	98·0	96·0	89·0
Mean	92·5	96·0	94·5	89·0
Time taken to root in weeks				
N.29	12·4	13·5	13·3	14·6
N.71	13·7	14·2	14·5	17·6
Mean	13·0	13·8	13·9	16·1

The percentage of rooting was increased, as is shown, but most important of all the time taken for the cuttings to root was significantly decreased.

A great deal of work has been done on the treatment of Arabian coffee cuttings with hormone substances at the Scott Agricultural Laboratories, Kenya,[6, 20] and a new technique for the injection of these substances into the tissues of the cuttings has been evolved.

The solution is placed in a vacuum desiccator and the bases of the cuttings are immersed in the solution. The lid is closed and the air exhausted to a negative pressure of 60 cm. of mercury. The vacuum is maintained for a period of from five to ten minutes during which time air is withdrawn from within the cuttings and bubbles up through the solution. On releasing the vacuum, the solution takes the place of the air and the cuttings are allowed to absorb the solution for a similar period. It is claimed that this method reduces the time of treatment from twelve to eighteen hours to a few minutes and effects a considerable economy in the amount of solution where large batches of cuttings require treatment, since the same solution can be used many times over. Experiments have indicated that the vacuum treatment gives better results than the former eighteen-hour treatment.

Earlier experiments in Tanganyika using 'Hortomone A' in various concentrations gave no significant results, though the indications were that this substance accelerated rooting. There was, however, a strong suspicion that the difference in capacity to root between different trees was greater than the general response to the root-promoting substances.

Following the work so far accomplished by these and other authorities, one must expect that most of the known root-promoting substances used in correct dilutions and by improved techniques will accelerate and improve the rooting of coffee cuttings. A 90 per cent rooting within three to three and a half months is now possible and it remains to improve the methods of potting and after-treatment to reduce the deaths by other causes.

ROOTED CUTTINGS IN POTS

Nothing like so much research has been used in connexion with the after-treatment of rooted cuttings, because common practice in the tropics has been followed without more ado.

For instance, banana fibre or locally-made basket pots are not very efficient

or desirable. They have two advantages which give the reasons why they have been commonly used: (*a*) They are cheap and can be made locally of local materials (*b*) they can be set in the ground together with the plant at planting time, for they will then disintegrate. There is no need to turn the plants out of their pots, and one might add that they need no drainage.

They have many drawbacks. They often begin to decay and fall to pieces before the time is opportune for planting in the field. The chief drawback is that they dry out too quickly unless moist sand, ashes or some other materials are packed between the pots, and unless their surfaces are protected while they stand in rows, with some form of mulch placed between the plants. All this, of course, hastens the decay of the pots, and for this reason such beneficial practices are disregarded. In an ordinary earthenware pot, space is left to be filled with water at the time of watering, but with fibre or wicker pots there is no object in this since it leaks away almost at once.

Endeavours should therefore be made to manufacture and use better containers, or import some of the cheap non-absorbent fabric pots that are marketed nowadays.

As for potting mixtures a little has been done at Lyamungu and elsewhere to try out various ingredients, and it was shown that improvements could be obtained. For instance, a compost—leaf mould—fine sand mixture at a ratio of $3 : 1 : \frac{1}{2}$ by volume, was adopted in 1948 in Tanganyika, though the death rate was eighty-six among 457 potted plants. Most authorities agree that a rich compost material mixed with a little sand should be used, and the cuttings potted up when they have roots one to two inches long.

According to practice the potted cuttings are returned to the propagating frames for a period of three to four weeks, after which they are moved out 'to some shady spot' for a period of two to three months, or are planted in nursery beds under shade to await field planting.

Some shady spot might be anywhere—under nearby trees, for instance, which most certainly would not be good enough. In fact, the potted plants require more care than the cuttings while they are rooting in frames.

A plant in a pot is most unnatural and is generally unhappy. The roots are restricted, the young plant is deterred from sending moisture-seeking roots downwards to the depth desired, and the soil is either too wet or on the point of drying out—rarely of the right moisture content for any length of time. Often the temperature of the soil in the pots must be much higher than it should be.

Advice about potting mixtures might well be sought from the John Innes Institute, and much more attention should be given to this matter. As for standing the pots in the shade, there should be a properly constructed floor on which to stand the potted plants in grouped rows. Provision should be made for movement between them and proper artificial shade overhead, preferably of a roller-blind nature so that this can be removed during dull and wet weather to give more light and to avoid drip. Care should be taken to see that the hot afternoon sunshine does not slant across the pots.

Given proper attention in all these respects, when the pot plants are moved from the frames, there is still one benefit which they will miss and that is humidity. The nursery site should be protected from strong winds, and frequent mist sprays in hot weather would assist the plants to survive. Damping down the surroundings and the intervening pathways will help to cool the atmosphere, and the process of 'hardening off' to full sunshine before planting

must be done gradually. In fact, potted plants should never be subjected to full sunlight during the hottest time of the day. They will survive this and harden off when they are planted in the field, with their roots comfortably protected in the soil. Direct sunlight on pot plants in a tropical nursery is just not common sense.

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Chapter VIII

STARTING A COFFEE PLANTATION

Qualifications Required

TECHNICAL TRAINING

The time has long since passed when ex-soldier land settlement schemes are of any value. Nor is it wise for a banker, a stockbroker, or a lawyer to throw up his profession and start planting coffee. High prices and big profits may lure businessmen to the venture, but they must have a technical horticultural training, or alternatively engage someone who is fully trained to manage their estates. Nowadays a farm requires a technically trained farmer, and an orchard needs a man who is trained in horticulture, though agriculture and horticulture are complementary. Money has been wasted and land misused far too often in the past by men who knew little about either of these trades.

Throughout the British Colonies mistakes have been made by placing agriculturalists in charge of horticultural industries, yet orchard crops such as coffee, rubber, citrus or cocoa are grown so widespread that the finances of many countries depend on them. Very few horticultural men are listed on the staffs of government departments, and when they are, they are relegated to inferior posts, or have been engaged only during recent years.

A book such as this may give guidance to practical men who have been planting for several years, or to students who are beginning their training. Anyone who intends to become a coffee planter, however, should first seek training at a horticultural school, or spend at least two years as a pupil on a well-run coffee estate to learn the practical side of his job, devoting his evenings and spare time to a study of the methods used elsewhere. One cannot become a farmer or a coffee planter overnight.

LOCAL LANGUAGE

Coffee is planted in countries where the local employees have languages of their own, and to understand them and gain a happy co-operative spirit, also to make them understand what is required of them in their various tasks, it is essential for the coffee planter to master the local language. This he can do only by living in the country and by studying the language during his period of apprenticeship. It is no use employing English-speaking headmen, neither is it ever good enough to learn a sort of pidgin-English, for it does not gain respect. Many a labour shortage, labour strike, or a disastrous mistake can be avoided by knowing the language. It is a simple first essential which brings its full reward.

LAWS OF THE COUNTRY AND BOOK-KEEPING

A coffee planter must be a man of patience and determination, moderate in his habits and fit in his body and mind, if he wishes to live long in the tropics.

He needs to become acquainted with the laws of the country, and to have a sufficient knowledge of book-keeping to enable him to keep accounts; to know what is meant by capital and revenue expenditures, and how to fill in his tax returns in all fairness, and without loss to himself or to his employer.

CAPITAL REQUIRED

Then he needs capital; not too much nor too little. Few can survive the hardships and setbacks which the tropics can bring, if they have insufficient capital. Neither can riches bring success. Men who first build themselves a lovely house, surround it with a garden, buy themselves a car and hasten to belong to the local clubs, do not always make successful planters, yet there have been such men, and they live in memory and are pitied for having lost fortunes. The sum of £15,000 is not too much to bring a 250-acre coffee plantation into bearing, to suffice for living expenses for the first three or four years, and to have a little over for an emergency when the first crop is sold. To begin drawing advances on shipments is a false policy.

With such a sum a man must work hard and exercise thrift. He must live and work on his property from the very beginning, and use a tent until a temporary thatched shelter can be made available. A house may be dreamed about when he smokes his evening pipe, and planned for when the land has been fully planted and the first crop is ripening on the trees. As for transport, he must think in terms of a useful lorry, and remember that a light tractor is of greater value than a car.

MAINTENANCE OF EQUIPMENT AND HEALTH

Talking of tractors, the firms that sell them in the home country run useful short courses in care, maintenance and repairs, which might well be indulged in by fully-fledged planters who are home for a spell of leave. A course of first-aid is also a useful preparation, since plantations are often at a distance from a doctor and the planter is expected to aid his employees whenever they are in need.

Choice of Land

FIRST CONSIDERATIONS

A planter seals his fate when he takes over his land. His whole future for good or ill depends upon his choice, and the land should be chosen by nobody but himself. He may gain advice from local departments of Agriculture and Lands, and a great deal from acquaintances, especially those who have land for sale. Naturally he will have made himself acquainted with the requirements of coffee—the kind of soil it needs, the rainfall, and above all the temperatures. He will consider the distance from the coast and railway, and the nearest approach road, remembering that transport costs eat into profits. He should also consider the local labour supply, as to whether it will be adequate. During his early apprenticeship he should take every opportunity to travel, and not be satisfied with land which might be offering in his immediate locality. He may even find it necessary to venture into a new area where there are no established coffee plantations from which to draw comparisons.

The direction and prevalence of the wind may be important in hilly country,

for moisture from the clouds may be precipitated on one side of the hills but not on the other, and even though he knows the climatic conditions required, there may be no meteorological records near enough to give him guidance. He may be hunting for the ideal environment which is very hard to find, and if he gives way on one point or another because it is necessary to accept something less, then he may give way too much, and choose land which is unsuitable. Should the winds be too strong then he must consider wind breaks; if the rainfall is too short, there may be water available for irrigation or means to conserve moisture; if the temperatures are a degree or two too high, mulches and overhead shade may help to annul them.

LOCAL VEGETATION

A study of the vegetation is a great help, and advice should be sought from a competent economic botanist if one is available. Wooded and luxuriant growth near streams and swamps is of no significance, because it is the growth on the land area to be planted that gives an indication of the fertility and climate. If bananas grow well in the locality, on the same type of soil, then this may be a favourable indication, though bananas will flourish in localities where temperatures are much too warm. Forests should be of broad-leaved trees, with a rich undergrowth, and a carpet of ferns and broad-leaved plants; open land should be covered with luxuriant grass at least shoulder-high. This should not be of a persistent kind, unless it happens to be short-grass meadow-land rich with clovers at a higher altitude. Thorn trees that drop their leaves, and short grasses that shrivel and turn brown in the dry seasons indicate that the area should be avoided. The temperatures which coffee trees enjoy, and the high rainfall they need, encourage a vegetation which is always green and luxuriant, though consideration of this point may lead to a locality that is temperate and too cold. A visit to one of the most successful coffee-growing regions with eyes open to observe the surrounding vegetation will help to indicate the type of soil cover which should be found in a new locality. Much depends on which species of coffee it is desired to grow.

NATURAL ASSETS

Naturally the land should be as flat as possible, or gently sloping and capable of contour cultivation. If a corner of the land slopes too steeply up a hillside then this might be reserved for planting trees. Home-grown timber and firewood are always great assets. There may be a patch of swampy land near a boundary, and this might be drained and planted with Napier grass or bananas to provide mulching material. The gently sloping land at the foot of hills is always preferable to a valley floor, where cold kabatic winds might flow, or heavy mists form each night.

WATER SUPPLIES

Good clean water in plentiful supply is essential, and if it is not present, inquiries will discover whether it can be brought to the land from elsewhere by furrow. Hydraulic rams are useful for lifting water from distant springs. Domestic supplies will be required for the house and labour lines, and a more plentiful supply for pulping and washing the coffee. The lie of the

land may even permit of cherry coffee, during harvest, being flumed from a distant field by gravity to the factory. Every means of economizing should be examined from the beginning, for it is often difficult to introduce such schemes on planted land.

SOIL TESTING

When examining the land before purchase, it is wise to quarter the area and dig inspection pits at regular intervals to study the soil profiles, especially where there is any unevenness in the covering vegetation. A deep and crumbly loamy soil with good drainage is desirable, but a shallow soil, or a mixture of gravel and a sandy soil should be avoided. Remember that the soil should be near neutral, or have an acidity value between pH 4·5 and pH 5.

BUILDING MATERIALS AND TOOLS

It is an advantage to find building material near at hand: stone rubble for road surfaces and clay for bricks, though one must not expect too many natural advantages. A word regarding tools. A short experience of the country will inform one what to buy. It is no use buying spades when bare-footed labourers prefer digging hoes. A light tractor with attachments such as a plough, a road grader, and a ditching implement, will always be of use, but heavy clearing machinery can perhaps be hired locally if hand labour does not prove a more economic proposition.

SITES FOR BUILDINGS

Before beginning to clear the land a rough sketch should be made of its extent, and shape, and the sites marked in a preliminary fashion for the dwelling house, labour lines, factory, store sheds and drying ground. Alterations may have to be made when the land is laid bare, but it is as well to have an idea in the beginning of the possible location of estate roads, drainage system, and the division of the land into blocks of known acreage.

It is nice to reserve a plot of land at the highest point for the dwelling house, whence the plantation may be overlooked, provided a water supply can reach it. Many a shirker will forego his laze if he feels himself under distant observation, yet there are owners who prefer to be out of sight of the plantation when their day's work is done. Except for emergencies, the house must be out of bounds to employees at all times. Stores, tool sheds, and office buildings, should be clustered at a central point, and preferably on open land at a higher point than the factory. It is here where the sun-drying barbecues or trays should be situated, away from the valley mists and not shaded by trees during the afternoon sunshine.

The labour lines are best tucked away out of sight, where the prevailing winds will carry odours of cooking and noise of revelries away from the owner's residence. Yet they must be in a healthy situation, and well constructed; sheltered from storms and shaded with trees from the heat of the mid-day sun. There are often strict regulations concerning the provision of housing for plantation labour, and irrespective of these, it is in the owner's interests to see to the legitimate comfort of his employees. He depends upon them, so he should see to their comfort long before he begins to build his own house.

A factory site should be at low level near a good water supply, and conveniently situated for access from the estate. Room should be available for extension, and provision made to utilize the crop residues for making compost. As much use as possible should be made of gravity movements, both outside and inside the factory premises. Cherry coffee is heavy and it should always move downhill. It should then continue to move from a higher level through a hopper to the pulper, and the pulped coffee to separators and fermenting tanks. Washed coffee should be drained of moisture at the factory before it is transported to the drying ground, and if there is water power to be had, then so much the better.

MIXED FARMING

Two hundred and fifty acres of planted coffee are enough for one man to look after without additional supervisory assistance, for one assumes there may be ancillary patches of woodland, mulch growths, and food crops. If the land is not too dear, and a larger area is available, it might be wise to buy this as an investment for the purpose of an extension later on, perhaps, or better still for the purpose of mixed farming.

Provided a man has the requisite knowledge, mixed farming along with coffee planting has great advantages. One orchard crop such as coffee is nothing more than a so-called monoculture, open to the hazards of pests and diseases, of locusts and freak storms, if not to the ups and downs of market prices. If markets are assured, mixed farming is a safeguard provided it is embarked upon cautiously, and though animals may be tiresome things to look after, they do give additional amenities and help to build up fertility. The author would sooner see a smaller plot of coffee attached to a mixed farm, than one large plantation of coffee.

ARRANGEMENTS FOR RELIEF

Enough has been said to show what a tie such a venture will become. An Englishman cannot go on working for ever in the tropics, however, without a change of scenery—without, in fact, regular periods of leave in a temperate climate. His health demands it, his very outlook on life demands it—to keep his feet on the ground, to revive his energies and safeguard a lively acumen. A man who engages himself in coffee planting must have the foresight to appreciate these truths, and the fact that he may fall sick. He should arrange in good time for his relief, whether he has a son with his heart in the business, a trusted partner, or can arrange to employ a good manager. It may seem strange to mention such things in a book of this kind on coffee production, but it is surprising how often such considerations are forgotten. The type of man who ventures overseas often has a very necessary but sublime confidence in himself.

Clearing the Land

THE PRESERVATION OF SOIL COVER

If the land is sloping, as most land is, then it is best to begin clearing from the top of the rise and work downwards. Before long it will be necessary to construct a storm drain along the upper boundary. This will receive the flood

water which is likely to rush down during heavy showers from the slope above the property. If this protection is not provided, then sheet erosion and gullying may occur on the cleared land before planting has even begun, and this is the chief reason for starting the clearing operations at the top of a slope.

Although trees may be felled and the stumps uprooted throughout the land, all the herbaceous growths should be left as soil cover for as long as possible. Block by block the land is cleared, and the rubbish and tree roots burned in multiple fires, rather than one big blaze, which would be harmful to the patch of soil it rested on. Trees may be pulled over by the use of tackle and winch, so that the roots are torn out of the ground, and any fangs that remain may be pulled out by a tractor. Bulldozers and heavy tractors with chains, and so forth, such as have been used in recent years for clearing large areas of bush, are hardly necessary for the preparation of a plantation, for they tend to churn up the soil too much. Hand labour and smaller implements are generally more economical.

NOXIOUS WEEDS

Tree stumps and roots should be entirely eliminated because of the danger of root diseases such as *Armillaria* and because they interfere with subsequent cultivation. The land should be dug or ploughed about nine inches deep and brought to a rough tilth. While this is being done a sharp look-out must be kept for any patch of noxious weed such as couch grass. Agriculturalists may satisfy themselves by ploughing and raking the creeping stems out, relying on successive cultivations to depress the strength of the weed so that it will die out. This is not good enough for an orchard of coffee trees. The patches of weed must be eradicated completely by searching for every scrap that is likely to root and sprout. It is almost impossible to eradicate couch grass among planted coffee without harmful results to the trees.

USE OF COVER CROPS

As each block of land is cleared, cultivated, and cleaned, it should be sown with a good soil cover as soon as it is possible to germinate a crop. This can be ploughed in at any time to serve as a green manure. Soil deteriorates in structure and value very quickly in the tropics, firstly because of the baking powers of the hot sunshine, and secondly because of the pounding action of heavy raindrops. There may be cover crops which are particularly suited to the locality and in general use on other estates, in which case one cannot do better than use something which is of proved value, rather than try something which is not, but the following crops have been used successfully in many countries:

The velvet bean ...	*Mucuna pruriens* (L.) DC. var. *utilis* (Wall. ex Wight.) Baker ex Burck.
The kudzu	*Pueraria hirsuta* (Thunb.) C.K. Schneider. (*P. thunbergiana* Benth.).
Calopogonium ...	*Calopogonium mucunoides* Desv.
The lablab bean ...	*Lablab niger* Medic.

Should it be necessary to cover the ground for only a short while, then the following might be of more use:

The cowpea ...	...	*Vigna unguiculata* Walp., or *V. sinensis* Endl.
The pigeon pea	...	*Cajanus cajan* (L.) Druce.
Sunn-hemp	...	*Crotalaria juncea* L.
Tephrosia sp.	...	*Tephrosia candida* DC., or *T. vogelii* Hook. f.

It is unlikely that one or other of the cover crops mentioned in the two lists above would fail to give good service in an environment suited to coffee. They should be sown by hand or by seed drill in a manner similar to the planting of dwarf or broad beans. There are, of course, many other cover and green manure crops used in different localities of every coffee-growing country, and it behoves an intending planter to take note of these for himself.

USE OF EXPLOSIVES

Large tree stumps are often very troublesome to dig out, and if explosives are available, and the manner of their use is known, they can be of great value. Sticks of gelignite, or slabs of gun-cotton are the most handy to use, with ordinary commercial primers, detonators and safety-fuse. They should be handled carefully, stored in a cool place—not under a hot corrugated iron roof—and be kept under secure lock and key as one would treat a virulent poison. Detonators should not be stored in the same place together with explosive charges such as gelignite or gun-cotton, since a slight shock or a spark is capable of exploding them. Moreover they should be kept packed firmly in their box in an upright position so that they are free from dust and grit and cannot rattle when the box is handled. There is nothing to fear in regard to their use provided ordinary precautions are practised.

When ordering explosives of this nature it is necessary to state that the fuse must fit the detonators, and the detonators fit the primers, since different makes may be available. Gelignite is a soft, putty-like material wrapped in paper, and gloves should be worn when the explosive is handled, since it has a poisonous effect through the skin and will cause severe headaches.

In the assembly of a gelignite charge, one end of a stick is unwrapped to expose the explosive, and then a smooth, rounded pencil of wood, of the diameter of the detonator, is pushed into the soft material to make a hole about one and a half inches deep. The tube-like detonator with its proper length of fuse attached is then gently pushed into the hole. The loose frill of paper is then wrapped in position round the safety fuse and tied with string (*see* Fig. 11). It is important to assemble the fuse and the detonator before, and not after the latter has been pushed into the gelignite, and the assembly should be held by the fingers where the rim of the detonator has been crimped to the fuse, otherwise the fuse might be pushed too roughly against the sensitive explosive within the detonator.

Some authorities have other methods of assembly and make the hole for the detonator slanting into the side of a stick of gelignite. Having pushed the detonator into the charge the fuse is bound to the end of the charge with tape or strong cord. This permits the charge to be dropped into a hole without fear of the assembly loosening while it remains hanging.

First of all, before each day's work, a length of the fuse must be cut from the coil with a sharp knife and tested for efficiency and burning rate. It is then possible to time the rate, and thus compute the length of fuse required to

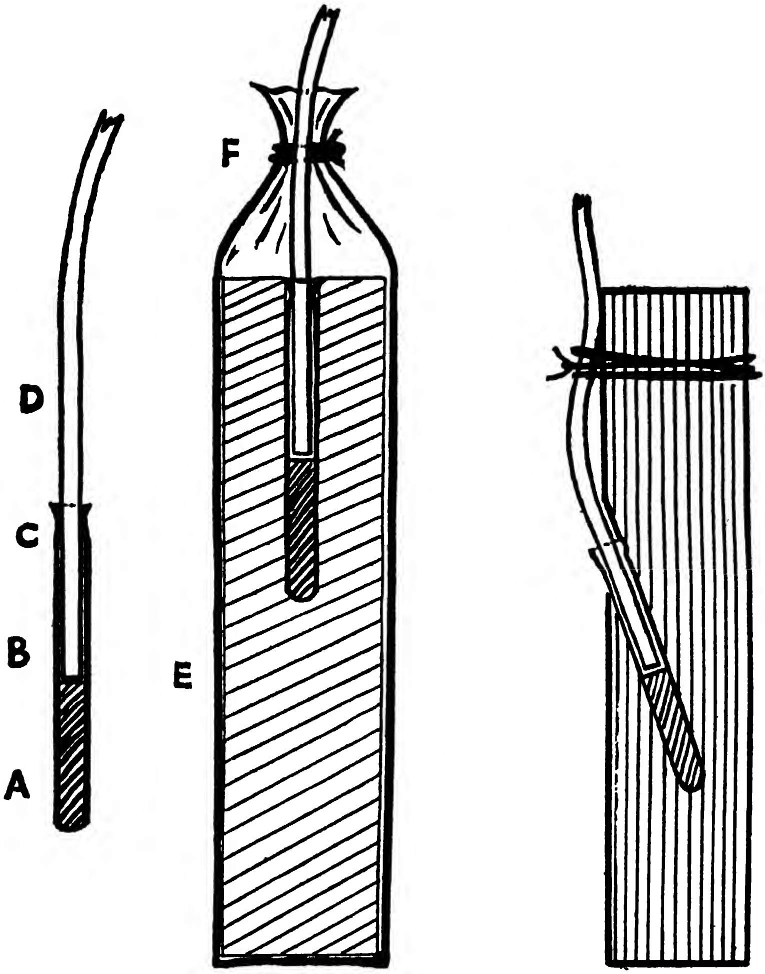


FIG. 11.—(A) Detonator explosive.
(B) Detonator tube.
(C) Tube crimped on to safety fuse.
(D) Safety fuse of tested length.
(E) Round stick of gelignite in paper covering.
(F) Paper cover frilled and tied round assembled fuse and detonator.

Assembly of safety fuse, detonator and gelignite when the charge is suspended for dropping into a hole.

allow for a safe retreat at a comfortable walking pace. A little extra length is allowed to give a margin of absolute safety. The end of the fuse to be lighted should always have a slanting cut to expose the powder in the core and thus ensure an easy lighting. Fuses are usually lit with a fusee match, though an ordinary match will suffice if the operator is not nervous. A slight hiss and a puff of smoke will signify without doubt that the fuse has been lighted.

A detonator is a thin tube of metal painted red about the thickness of a pencil, i.e., ¼-inch diameter and 1½ inches long. One end is open, and the

tube is about half-filled with a very sensitive explosive. Whereas only ordinary care is necessary for handling the main charge, one cannot be too careful in handling a detonator. It should be held away from the face, with the fingers of the left hand holding the empty part of the tube, and a slender blade of soft grass may be inserted to test the depth. A match-stick should never be used. The square-cut end of the safety fuse is then held in the right hand, with the thumbnail measuring the predetermined depth of the empty part of the detonator tube. The end of the fuse is then gently inserted into the detonator in such a manner that it is almost touching the contained explosive. Then, with a pair of small pliers, the rim of the detonator tube is crimped on to the fuse—never with the teeth.

When detonators are used in the field they must be kept shaded from the sun and packed in their box until they are required for actual assembly, and no one handling them should smoke a cigarette or a pipe. Care must be taken not to drop a detonator.

A pound slab of gun-cotton has a tapered hole in the centre in which a tapered gun-cotton primer about the size of a cotton-reel should fit closely but comfortably. A hole in the centre of the primer receives the detonator, and the safety fuse is fitted into the detonator in the manner already explained. The sequence of assembly is to fit the fuse to the detonator, then the detonator to the primer, and lastly the primer to the gun-cotton slab. If the detonator will not fit the hole of the primer easily it should not be forced into position. Provided the enlargement to be attempted is only a fraction of an inch, the hole may be gently enlarged by the use of a wooden peg or rectifier. (*See* Fig. 12).

In either case, whether gelignite or gun-cotton is used, the charge is naturally placed where it will be most effective. Of the two, the gun cotton will give a sharper smack, but to split up a large tree stump, the charge may have to be increased to three or more sticks of gelignite, or two or more slabs of gun-cotton. The one detonator will suffice, because the other sticks or slabs are packed firmly together with the assembled one so that they all touch each other. They will then detonate simultaneously. The first explosion may only split the stump and remove the soil about the roots in the form of a small crater, so a second charge may be necessary to break up the stump sufficiently to enable a tractor to pull out the fangs.

From the time the charge is placed, until the explosion has occurred, no unauthorized persons must be allowed to approach within two hundred yards, because pebbles may be flung with considerable force for a hundred yards or more. The charge is placed in a small hole dug deeply in a hollow between the tree root buttresses, and close against the trunk, and clay of a dough-like consistency should be gently pressed round the free side of the charge without covering or interfering with the fuse or the detonator. Having laid the fuse conveniently, and after a careful look round, the fuse may be lit by the operator who retires at once without undue hurry to a safe distance or to safe cover. Should a misfire occur, then the explosive charge must not be approached within an hour, and the first action afterwards is to remove the detonator and fuse. These may be demolished by laying them next to the charge after a fresh detonator and length of fuse have been assembled for the second attempt.

In the Services, and in war time, half an hour is given as the danger period within which no one is permitted to approach a misfire. Publishers and

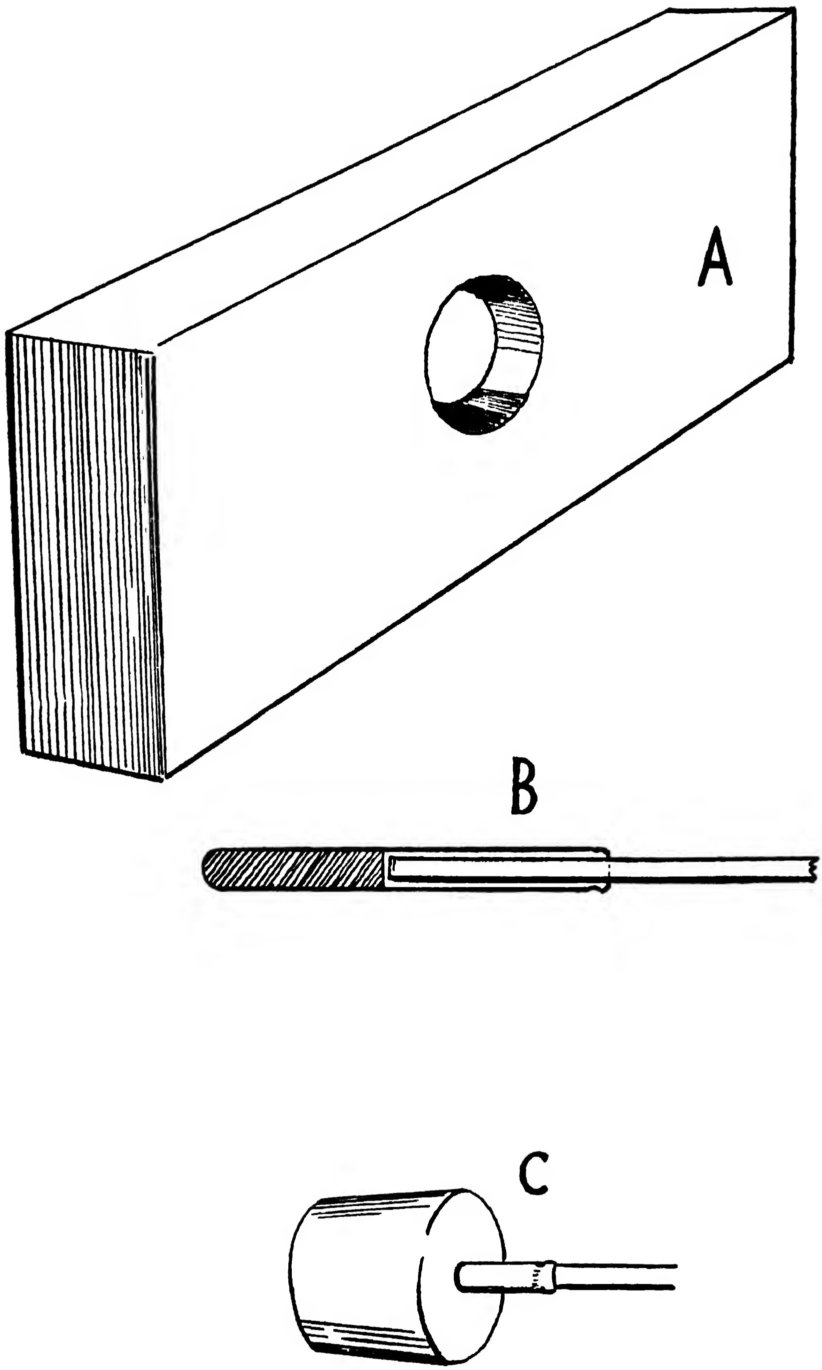


FIG. 12.—(A) 1 lb. slab of guncotton with tapered hole for primer; (B) Tested length of fuse is assembled to the detonator; (C) The detonator and fuse is assembled to the tapered primer which then fits into the hole of the guncotton slab.

authors avoid laying down a specified time. The chances of a misfire are small if proper care has been taken in assembling the charge. The interval of waiting should be as long as possible, for if there has been a fault in the powder train of the safety fuse, the lining of the core may smoulder for a while, especially if a strong wind is blowing, with the danger that the smouldering material might pass the fault and relight the fuse. It is never safe to return immediately to the charge and the interval of waiting should preferably be until the next day if the firing is done in the afternoon. In order not to waste time, one must make certain that the fuse is lighted by watching for the initial spit of flame and smoke before retiring to cover. Only one person should investigate a misfire and his mode of examination should be slow and methodical.[8]

There are, of course, electric detonators and also other kinds of explosives, including instantaneous fuse, but the author, who had considerable experience during World War II in the practice of bomb disposal, and has himself demolished tree stumps in this manner, would not advise anything else for such a purpose as has been described. Care in the use of explosives is all that is necessary, and then they can be useful servants for demolishing tree stumps and odd boulders of rock. A loose boulder is broken apart by placing a charge of gelignite on the top covered by a pad of clay, and in quarrying this is called 'popping'. When a charge is used for breaking up rocks above, or at ground-level, good cover must be sought from flying splinters.

Erosion Control and Moisture Conservation

THE CAUSE OF EROSION

One must assume that the whole area has first been cleared, or that a sufficient portion of it has been cultivated for the first season's planting, beginning from the top boundary. Before the lining and holing for planting can be done, the land must be protected to ensure that no erosion takes place, for when the balance is upset by the removal of the vegetation, accelerated erosion sets in, and, unless it is checked by adequate treatment, becomes steadily worse and leads to the eventual ruin of the land.[7]

If the land is gently sloping then the work will not be difficult, but any part of it which is steep will need greater care. A gentle slope which might never be eroded in a temperate climate would not be safe in a high rainfall area of the tropics. Rain may fall steadily and heavily for several hours, and cause flooding as the pores of the soil become temporarily saturated. Furthermore, one must expect storms with falls of an inch or more within half an hour. There may even be freak storms occurring every four or five years, when a rainfall of as much as five inches in one hour may be experienced, and it is wise to prepare for the worst and not for the usual and average amount of rain. It is better to miss a planting season if the work of clearing has been delayed, rather than suffer erosion in subsequent years, since proper safeguards cannot be provided after the land has been planted.

It is the velocity of water running downhill that causes erosion: both sheet erosion which steals away the top soil at an insidious but steady rate, and gully erosion which causes great canyons to appear in the natural folds of the land, wherever there have been slight hollows and water has collected in rivulets. It is the velocity which must be slowed down, and the surplus water

must move sluggishly away along the contours of a very gentle gradient towards natural drainage or prepared storm drains. In theory, if the rate of flow is doubled, the scouring capacity is increased four times, the carrying capacity thirty-two times and the size of the particles carried sixty-four times.[7]

When the velocity of the water is slowed down it lies for longer on the land as it flows away, so there is more time for it to soak in and replenish the moisture reserves in the sub-soil. The higher slopes of land benefit, while the lower slopes are saved from a surplus and hence do not become too wet. In fact, therefore, erosion prevention not only stops the wash of soil downhill, but it conserves moisture, a very useful means to increase the moisture in the soil when the rainfall is a little short for coffee.

SUB-SOIL MOISTURE

Few people realize, even in these enlightened days, that a shortage of rainfall is felt mostly because sufficient moisture does not reach the sub-soil to replenish the amount drawn away by crops. Coffee that needs an eighty-inch annual rainfall can do with forty inches provided those forty inches are conserved and the sub-soil is kept moist. Below growing crops there is generally a deficit in the sub-soil by the end of a dry period, and this must be made up during the next wet season or subsequent crops will suffer. The health of a coffee orchard and its regular yields depend more on the available but sweet moisture supply in a well-drained sub-soil than people imagine. It is more valuable than many tons of artificial fertilizers or organic manures, so even if the potential planter is perturbed at the amount of work involved in safeguarding his land, the yield and health of his orchard will more than repay him for his endeavours, on account of the moisture which has been conserved. No word of advice in this book can be more sincere, or need greater attention.

CHECKING THE VELOCITY OF FLOW

The storm drain along the top boundary of the property will stop water flowing on to the land from above, but below this check, the water will flow down the sloping land and begin to gather speed. It must be checked again before that speed becomes too fast, and this can be done satisfactorily only by constructing broad-based ridges along the contours at appropriate intervals, on reaching which the speed of the water will be checked again and again on each succeeding intervening slope. If the ridges are sufficiently strong and high, and the hollows above them lie at a proper gradient, the water will then flow sluggishly away to a place where it may escape in safety without harming the land.

On account of the varying slope, and the fact that the gradients of the ridges must all be the same, the spacing of the ridges one from another will vary in wavy lines. They will come closer together on a steeper slope, and be more widely spaced on a gentle slope. It is, therefore, the vertical distance apart which matters, not the distance at ground level, because the water will gather speed quickly on a steeper slope in a shorter distance and hence the checks must not then be so far apart.

Abrupt or narrow-based ridges constructed across the land would not only

look unsightly but would hinder the working of an estate. The ridges must be very broad, and at least thirty feet wide at their bases, though not more than about one foot six inches high, with corresponding wide hollows of the same depth above them. When these have been solidly constructed by ploughing to and fro, and by throwing the soil towards the centre, they will remain in position indefinitely and need only very little maintenance. Trees and crops may be planted on top of them, and in the hollows, and there will be no difficulty in using mechanical equipment over their surfaces. The whole land may be ploughed north and south or east and west but the ridges will still remain intact.

With a tractor, a plough, and a road grading implement, it is inexpensive and easy to construct these contour ridges across the land, provided the work is done in the beginning. The spacing of the ridges must first be marked out, of course, and this is done by pegging trace lines. At the time, as the trace lines are pegged across the cleared and cultivated portion of the land, they may also be pegged on the uncleared portion of the estate by cutting trace lines through the vegetation, so that the whole anti-erosion scheme is marked out and shown to scale on an ever-growing plan of the estate. It is necessary to trace out the sites for the ridges over the major portion of the land before one can decide where the surplus water is to flow. By collecting the excess water and directing it to flow sluggishly towards escape channels, a considerable volume of water may collect in the drainage system, and care must be taken to see that it does not cause damage by flooding someone else's land below. This is unlikely to occur if the job is done properly, for the very fact that the water is running sluggishly off the land, means that more will soak into the sub-soil.

Disaster may occur if directions are not followed, or if the work is done slovenly. For instance, if anti-erosion ridges are first constructed on the lower half of an estate, and a storm occurs before the upper land is similarly protected, then the amount of water rushing downhill will collect in such volume and with such force at the first ridge, that a break-through will occur, and most of the top soil will be deposited at the bottom of the slope. Construction work must begin at the top and proceed downwards, and there must be no fear that the storm drain at the top will not be of sufficient size to carry all the flood water away. Flood water must not be allowed to escape haphazard on to neighbouring land even though it may be unoccupied. Apart from the damage it may do to this land, it may cause a gully and head back on to one's own property. The task of curing a deep gully becomes an engineering feat of some magnitude, and a very costly one at that. For this reason, open ditches and storm drains should not be taken vertically down a slope, and if this cannot be avoided then they must be stepped down with a proper system of concrete barriers.

Well-meaning friends may talk of using contour hedges of grass or shrubs, of digging tie-ridges or silt pits and such-like palliatives. Such methods may suffice for agricultural crops, but not for a permanent orchard. Wherever there is a fold and dip in the land, water will collect and flow downwards, breaking through hedges, and filling the tie-ridges or silt pits with such frequency that there will be frustration and the recurring need to empty the silt from the pits. Elsewhere, in Chapter XI, mention is made of how to preserve the porosity and crumb texture of the soil which aids in absorption, since constant cultivation can break down the soil structure, destroy its

absorptive properties and thereby increase the run-off from the land. There is always some newcomer with a bright idea, who does not know that his plan has been tried before and proved a failure. It is wise to turn a deaf ear to such importunity, and to abide by trusted and proved methods.

BROAD-BASED CONTOUR RIDGES

Broad-based contour ridging has now a wide application in the United States, in East and South Africa and there are two kinds in use. The one advised in this book is sometimes known as the Mangum terrace system after Priestly Mangum, a North Carolina farmer, while the other is called the Nichols terracing after M. L. Nichols of the United States Soil Conservation Service.

Nichols terraces are constructed by taking the soil from the upper side only, and developing a deeper channel on the upper side, the bottom of which is well below the level of the surrounding land. The system has been somewhat blindly followed by conservation officers in some localities in East Africa, though it has considerable disadvantages. Its use is recommended in the United States in areas where the rainfall is unevenly distributed, and hence in regions which would not be chosen for planting coffee, its purpose being to conserve moisture to a maximum degree while checking erosion at the same time. The disadvantages are, of course, the hindrance to movement, transport, and tillage, by the higher mounds and deeper channels above them, and the fact that it is difficult to plant permanent crops on the mounds and in the ditches above them, especially where the subsoil has been bared and thrown up to make the mound. It is in fact difficult to use the space devoted to these mounds and ditches, and hence, if this system is adopted, it is best to sacrifice the space and leave it unplanted, in which case the wide rounded tops of the mounds may be used as roads. The Mangum ridge and hollows are so shallow that they merely form a wavy surface to the soil. They are never so costly to make and maintain, and they may form part of the planted area or be used as roads at the whim of the planter.

The vertical drop and the horizontal spacing between the ridges vary with the slope of the land, the character of the soil and the rainfall. If rainstorms of great violence are to be expected, or if the soil is one that is easily eroded, then the distances should be less than those advised. On the other hand an equable climate with a considerable, but well-spread rainfall, and a crumbly loamy soil, may permit the distances to be greater. The maximum slopes permitted for terrace ridges in the United States are between 8 and 12 per cent, though in East Africa ridging is employed on slopes of up to 15 per cent. The author would not like to use contour ridging on a slope of more than 12 per cent, knowing that the distance between the ridges (not between their centres or the trace lines) would not be more than fifteen yards with a vertical drop of five feet. Any land with a slope of more than 15 per cent would have to be protected by making bench terraces, a proposition so expensive, and so wasteful of planting space, that it can hardly be recommended for planting coffee.

A table is given concerning the practice adopted in Kenya, Tanganyika, and Nyasaland.

Slope %	*Vertical drop between ridges (feet)*			*Horizontal interval between ridges (feet)*	
	Kenya	*Tanganyika*	*Nyasaland*	*Kenya and Tanganyika*	*Nyasaland*
1 - 3	2 - 2¾	2 - 2¾	2½ - 3	200 - 100	150 - 100
4 - 7	3 - 3¾	3 - 4	3 - 4	100 - 50	100 - 57
8 - 11	4 - 4¾	—	4 - 5	—	57 - 46
12 - 15	—	—	5 - 6	—	46 - 42

Beckley[3] states that for most of the soils in Kenya, the United States spacings would be applicable, and the present author has used them with success.

Spacing of Terrace Ridges:

Slope of land per 100 feet	*Vertical distance between terrace ridges*
Less than 1 foot	1 foot
1 ,,	2 feet
2 feet	2½ ,,
4 ,,	3 ,,
6 ,,	3½ ,,
8 ,,	4 ,,
10 ,,	4½ ,,
12 ,,	5 ,,

THE DIFFICULTIES OF TERRACE RIDGING

Whether or not terrace ridging should be adopted depends on the configuration of the land. It is easy to talk about it on paper, but it is not so easy to carry it out in practice. The ridges themselves are easy to plan and construct, but the difficulties arise when the drainage is arranged, as will be seen when this is discussed. Natural drainage presupposes the existence of a stream, a river, or rocky gullies conveniently situated on the land. There may be nothing of the kind, or the gullies may be ravines so steeply-sided and deep that it would not be easy to arrange for the escape of water from the plantation terraces and storm drains without causing subsidiary gullying. The drainage system needs most careful thought and foresight, and if the storm drains must fall at a steep angle, then it entails considerable labour and expense to step them down in a safe manner.

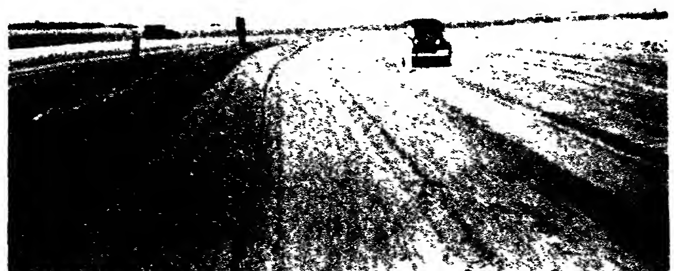
One must not give up the idea of ridge terracing too quickly, but, if the slope is not steep, and the configuration of the land is too difficult for easy drainage, then there is only one other system which might suffice. This is known as strip cultivation along the contour.

STRIP CULTIVATION

In place of the ridges, and at the same spacings, wide strips of land may be planted with stout grasses to break the velocity of flowing water, and catch much of the silt. The best grass to use is Napier grass (elephant grass) *Pennisetum purpureum*, of which cuttings could be planted on belts of land not less than fifty feet broad, at right angles to the slope. At the same time the banks of all natural watercourses, gullies, and streams, would be planted with

(*a*) A typical narrow-based ridge terrace in Basutoland

(*b*) Narrow-based ridges on fairly steep land—Basutoland



By courtesy of L. H. Collett, Esq., O.B.E., and the Commonwealth Bureau of Soil Science

(*c*) Broad-based Mangum terrace in Colorado. Bank is 30 feet wide x 2 feet high, and back furrow is 24 feet wide. These are advised for estate practice

PLATE XXX

trees or similar grasses. A careful watch must be kept to stop any new gullies starting on the cultivated areas.

Strip cultivation is usually applicable to agricultural crops of an annual or biennial nature, but there is no reason why it should not be adopted for an orchard crop, especially as the grass could be cut and used to mulch the coffee. Extension workers have recently advised planters to set aside blocks of land on which to grow mulching material, and the strips of tall grass would be adjacent to the coffee and therefore convenient for the purpose. They would mean a certain wastage of land, but this would not be serious if the young growths were used for silage, or grazing for livestock. Care might have to be taken to guard against grass fires, but the risk would be small if the ends of the strips were isolated from the countryside. The grass would flourish and be persistent if balanced fertilizers were used, and these would have a better application than if they were placed directly on the coffee land.

The growing grass would protect the coffee from strong winds, and to a certain extent the strips might help to isolate pests and diseases which were incidental on the estate. If they were correctly sited along the contours, there would be nothing to prevent contour ridges being constructed at a later date, if the protection afforded by the grass strips was not adequate.

PEGGING THE TRACE LINES

The tools required for tracing the gradients of the anti-erosion and water-conserving ridges are as follows: a dumpy-level or road-tracing instrument, a staff with a movable target, a number of pegs, a mallet and a fifty-foot chain. On open ground one helper would be necessary, but in thick vegetation others would be required to cut down the growths ahead along the lie of the land.

The tracing implement might be home-made. It may be a small, one-foot square table, with a sighting tube or other improvisation such as a large spirit level pivoted and fixed at the centre, so that it can be turned in any direction in a strictly horizontal plane. Sighting rings with cross wires could be attached to the spirit level. The table must be fitted with fixed tripod legs, and light enough to be carried easily and set up quickly so that the table is absolutely level and horizontal in all directions. The staff should be a stout piece of timber somewhat longer than the height of the tracing instrument. A disk of painted wood, i.e., the target, is arranged to slide on the staff, but is kept in position by a simple ratchet or locking device, the ratchet resting in notches corresponding to a measured scale in inches, half-inches and quarter-inches. Since wood will not stand up to hard wear, the ratchet device must be of metal fastened to the target and staff. The target is first set at a height on the staff which corresponds exactly to the height of the sighting instrument when both are on level ground, and the staff should be clearly marked to show this point. The target may be painted white with a horizontal black line across its centre.

First, the sighting instrument, which we will refer to as the S.I., is set up over the first peg, and it may help if a plumb-bob is hanging from beneath the centre of the table centred over the peg below. The staff is then taken fifty feet away by the helper, who soon becomes used to judging the contour of the land, and the distance is measured by the fifty-foot chain he drags behind him, which is attached at the S.I. end by a loop to the first peg.

If a level tracing is required, the staff is moved up- or downhill until the target cross-line is level with the cross-line on the S.I. The helper hammers a peg into the ground, the S.I. man releases the chain and moves to the second peg, where the operation is continued.

Supposing a fall in gradient of one inch in 100 feet is required, and remembering that the chain is only fifty feet long, the target on the staff is moved up half an inch, so that the length of staff below the target is now longer by half an inch. When the target is level with the S.I. then the correct fall in gradient has been obtained. For a rise in gradient the target is moved downwards.

Graded ridges are better than level ones, for they allow the water collecting in the hollows above them to flow away at a slow pace. It has been found best to have a variable grade, starting with a very slight grade and increasing gradually to a maximum of 1 in 200.[3] Water collecting in the steeper grade flows away before there can be a great increase from the upper reaches of the run, so the possibility of the ridge being overtopped is thus removed. The variations are made about every 300 ft. in accordance with the table:

Length of ridge	*Drop per 100 feet*
0– 300 feet	½ inch
300– 600 „	1 „
600– 900 „	2 „
900–1,200 „	4 „
1,200–1,500 „	6 „

The maximum length of a graded terrace ridge before it empties into the drainage system should, therefore, be 1,500 feet, and it is not always easy to arrange such a short run. The run of the ridge may be twice this distance if the gradient falls two ways from a central high point, so that the water escapes to the drainage systems at both boundaries of the land in question.

The grade run of a ridge terrace may be made longer, only if the spacing between the ridges is made narrower, and the hollows (or ditches) above the broad-based ridges are as wide as possible and basin-shaped to spread the flow of water. The trace-line pegs must be stout, flat-topped, of the same length, and tapped down to the same depth in the soil, so that one-and-a-half-feet lengths jut above the surface of the soil. These will give guidance in constructing the ridges to the proper height.

The starting point for the top ridge is fixed by measuring from the top the correct vertical distance for the slope of the field. Set up the sighting instrument high enough, so that, when level, the line of sight will clear the highest part of the slope. Have the staff set at this highest point and read where the cross-wire cuts the staff. Suppose this to be 1 ft. 3 in. Move the staff 50 ft. down the slope and make a second reading, and we will suppose this is 4ft. 6 in. The difference in level is 3 ft. 3 in., or a slope of 6½ ft. in 100 ft. From the table it will be seen that the vertical spacing for slopes between 6 and 8 ft. per 100 ft. is 4 ft. Now set the target on the staff to 5 ft. 3 in. (1 ft. 3 in. at top and 4 ft. for spacing), and have the staff moved downhill until the cross-wires cut the centre of the target. This is the starting point of the first terrace, or the highest central point for a two-way ridge provided a drainage outlet is possible at both ends. If so, then peg this point with a master peg, indicating that this is the middle high point of the field.

From this point the graded trace line is made, first one way and then the other, and the target is set to give the correct gradient, and varied according to rule, i.e., the target should be raised $\frac{1}{4}$ inch at each 50 ft. station until 300 feet have been covered, and then the target is raised $\frac{1}{2}$ inch at every sighting until 600 feet have been accomplished, and so on until the run is complete. The gradient at the end of a ridge terrace should never be more than 3 in. per 50 ft. Sightings should not be taken at distances beyond 50 ft. Before starting to trace the second terrace the slope of the land is measured again at a point below the master peg of the first terrace, and having ascertained the vertical drop, the next line of terrace may be traced.

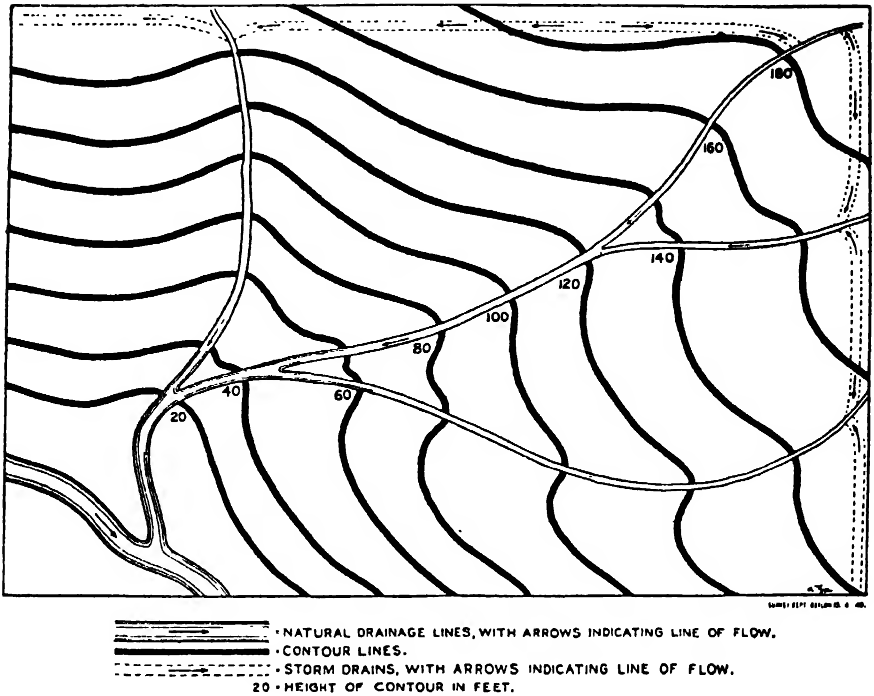
It will now be noticed, especially when the contours vary somewhat abruptly, that the lines of pegs follow an erratic course with various sharp-angled bends. A curving line is desirable and this is obtained by moving some of the pegs up or down the slope. Wherever they are moved they should be tapped into the soil so that their tops are level with those that were first aligned. It will be seen, then, that wherever a peg has been moved upwards the ridge need not be so high, whereas when it has been moved downwards the ridge must be constructed to a somewhat higher level.

Obstacles may be found which might necessitate the movement of the entire trace-line a little further up or down the slope, and this will not matter much if the slope is gentle. Ant hills may be blown up with a charge of gelignite which should succeed in killing the termite nest at the same time, and loose boulders of rock may be disposed of in the same manner. If the obstacle cannot be removed there is nothing one can do beyond stepping-down a short drain to the next terrace, with some stone protection at the bottom where the water will impinge on the next ridge. The first terrace can then be carried on beyond the obstacle, and the lower one be spaced nearer, so that it can cope with the extra volume of run-off.

BUILDING THE TERRACES

Building the terraces by hand-labour is a slow job, and yet at this point it may be just as well to relieve the reader of a certain amount of mental depression. He may picture a tremendous upheaval, and conjure up visions of work that is beyond his means, whereas, throughout a big field of gently sloping land only two, or at the most three, of these ridge terraces may be required. He may not aim at clearing and planting up his 250 acres or more in one year, and hence the construction may take place over a period of two or three years, provided he has begun at the top of the slope.

The usual method is to use a tractor and plough, with, perhaps, scoops or road-grading implements to move the loosened soil. These additional implements do help in getting the job done, but they do move the top soil over to the pegs first, and then, as the bared subsoil is subsequently ploughed, the top soil is buried by the subsoil. It is better if time can be given for the soil to be moved more slowly towards the pegs by the plough alone, as it moves along one side and returns by the other. This means that the plough is started close to the line of pegs, and when the width has been completed the same land must be ploughed again and again until it is mounded to the correct height. It may be necessary to break off for a while to give time for the soil to settle and consolidate sufficiently, but in this manner the top soil is not so likely to be buried. Not that this matters so very much if the bared subsoil



By courtesy of the Commonwealth Bureau of Soil Science

FIG. 13.—Natural Drainage Lines.

is dressed with well-decayed compost or farmyard manure to give it life, before the last ploughing is done.

On some soils the whole job may be done in much shorter time by dispensing with the plough and using a grading implement or a ditcher alone. No matter how it is done the soil must be mounded until the correct height is reached, and any depression should be filled with a shovel. When incipient gullies are crossed, care must be taken to strengthen the ridge, and raise it higher to allow for settling. It is no use filling the gullies with soil before the ridge is made, because the first rain would wash it away.

MAINTENANCE OF TERRACE RIDGES

The ridges will repay close attention and care during the first year. They should be inspected after heavy rain and any weaknesses strengthened, with special attention given to where they cross gullies. For the first few years on steep slopes it would be wise to cultivate the land parallel to their length. Cultivation across the ridges on mild slopes may be done only when they have fully settled down. It would be wise to sow the ridges with a cover crop for the first year to help bind the soil in position.[3]

In subsequent seasons if ploughing can be done and not interfere with the young coffee, the soil should be thrown towards the centres of the terraces every time, since the hollows above them tend to fill up with silt, unless mulching is practised.

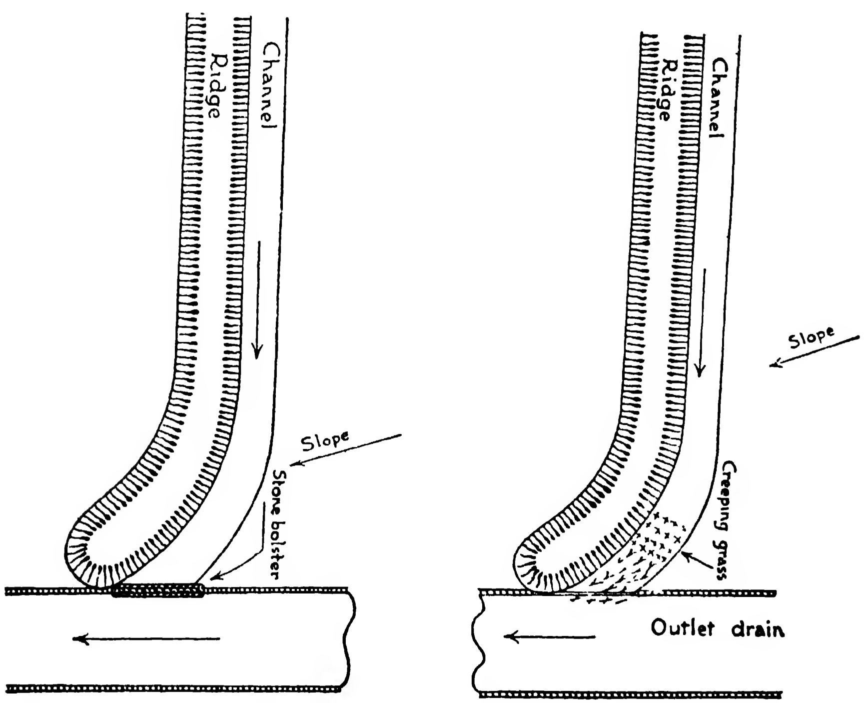
Returning to the need for mulching material, if the land space could be

spared, it would be ideal to plant the contour ridges with Napier grass, for this would help bind the soil, save maintenance costs, and assist in providing the mulch.

THE DRAINAGE SYSTEM

OUTLETS TO NATURAL DRAINAGE

Wherever the end of a ridge is brought to a river, a rocky gully, or natural drainage, such as a swamp, the ridge must bend at its end with the direction of the flow in the drainage channel and not head into the flow, otherwise flood water may surge along the terrace and top the ridge. One must inspect and study these drainage channels beforehand, to discover their potential flow during heavy rain and thus know what precautions are necessary for the protection of the terrace outflows. The ends of the ridges may have to be faced with cemented stone, or it may suffice to plant them thickly with a tough creeping grass. Care must be taken to see that where the water outflows from a terrace into the drainage channel, gullying does not take place and head back along the terrace. Such a disaster is hard to check or cure when once it has started, and gullying causes the ultimate cave-in of the whole end of the ridge. The damage thereafter would be accumulative. Emphasis must be placed on the fact that the development and maintenance of the drainage system may be more difficult, and is more important than all the ridge-terracing on the land.



By courtesy of the Commonwealth Bureau of Soil Science

FIG. 14.—Ridge Outlets.

Sometimes a concrete sill or stone bolster must be built across the end of the hollow above the ridge where the run-off flows away, or in the best circumstances it may only need planting with creeping grass well beyond the point where flood water from the drainage may rise and join the run-off flowing into it.

The banks of all gullies, rivers, streams or dry watercourses used as natural drainage, must always be covered with natural vegetation or be planted with creeping grasses of which the Kikuyu grass, *Pennisetum clandestinum* Hochst. is a good and useful example, or one of the creeping Star grasses used so frequently in the tropics for making lawns.

STORM DRAINS

Storm drains must be large enough in cross section to take the maximum flow, and where possible they should be graded down a slope to take water zigzagging from point A to B, and B to C, as gently and slowly as would a terrace ridge. Stepping them down should be as infrequent as possible and yet introduced whenever necessary. They should be wide and shallow, rather than deep, their width made wider, rather than deeper, to cope with a larger flow. Their sides should slope in a wide V, and the whole drain be planted with creeping grasses. It is often useful to plant the sides with the flowering or edible Canna, which grows profusely; the latter are of use for feeding livestock, though care must be taken to see that the Cannas do not choke the channel.

Since it is necessary to widen the storm drains as they collect more water and reach the lower slopes, they may be developed as wide and shallow water lanes planted with meadow grasses.

Stepping-down storm drains

Drains which are taken down a steep slope must be stepped-down, so that each step is level. The water flows as it falls from one step to another and the drains should be of a size to cope with the maximum flow. They should be wide rather than narrow with their sides slanting and planted with grass. Each step must naturally be below the level of the ground (*see* Fig. 15), and it must have a stone or concrete lip over which the water flows and against which the silt is held to prevent scouring. The face and sides of the step both above and below must be faced with stone on solid foundations, where the water shoots over the lip and curves downwards on to the next step. Some authorities advise a stone splash surface where the water falls,[7] but others advise a hole filled with water to act as a water cushion.[3] If the hole is fretted by the water itself, it usually reaches its limit of size and is then stable, provided the step is level, and a water cushion may cause less erosion of the sides of the drain than a splash stone.

PREPARING FOR PLANTING

ORDER OUT OF CHAOS

While the ridges and the drainage channels are being constructed, cleaning-up operations should follow. There will be debris lying here and there resulting from tree clearing, much of which requires tidying up before the next

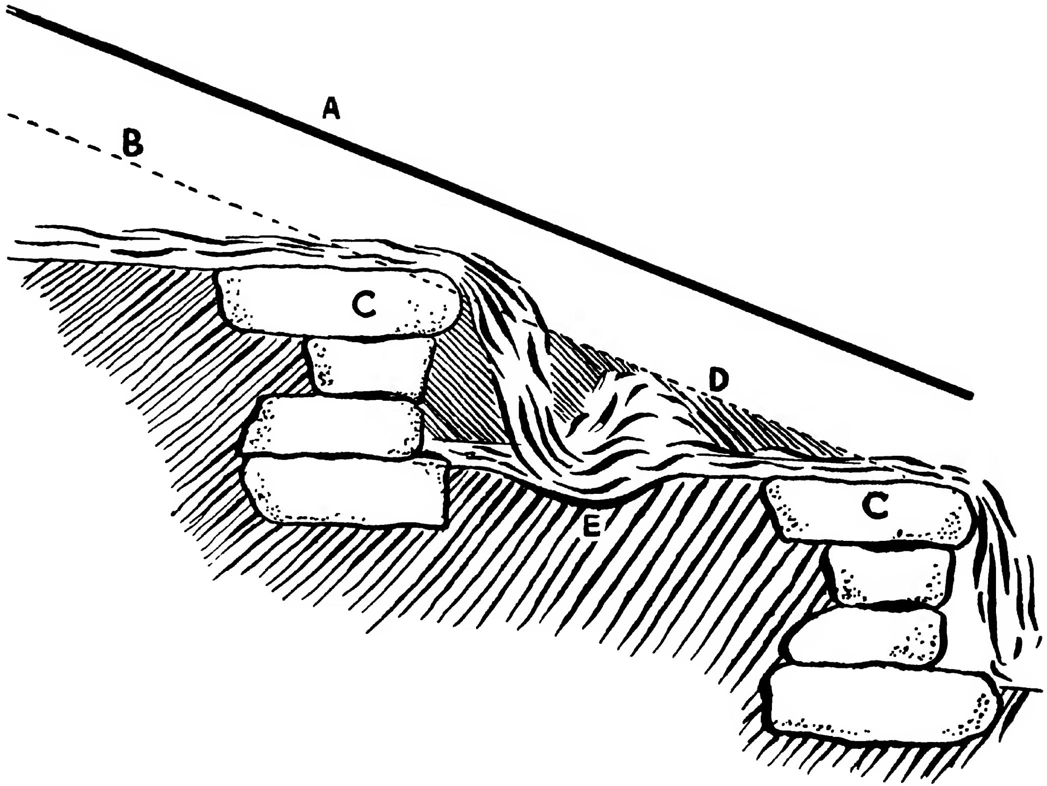


FIG. 15.—A stepped storm drain. A—Sloping ground level. B—Depth of drain. The sides are V-shaped and grassed. C—Strong stone or concrete steps on solid foundation. D—Triangles at each side of splash should have stone or grass protection. E—Falling water scours out bowl which should become static and form a water cushion. Splash stones cause turbulence and erode the banks.

Notes.—1. The steps are not so near if the slope is less. 2. Drains should be wide rather than deep.

task. There is an advantage, as will be seen, in lining and holing out as long as possible before the plants are set out, and there is no reason why part of this should not be done as the blocks of land, one after another, are brought into a state of readiness. Meanwhile the nursery site will require clearing, development and construction as the time approaches for raising plants, so that no time is lost. Arabian coffee takes from two to four years from the time it is planted to bear its first good crop, and it is to be hoped that it will take the longer period of time for this will prove, not only that it has been planted young and trained with care, but that the environment is a good one for coffee. If coffee bears too early it is a certain indication that the temperatures are too warm and that the conditions are not ideal.

ESTATE ROADS

Service roads

The lay-out of the roads will depend upon the contours. In general the main road enters and takes traffic along an easy gradient to wherever the office, the store sheds and the drying grounds happen to be, and then onwards to the factory. This road should be wide enough and strong enough to take lorry transport in all kinds of weather, which means that it should be underlaid with hard core, and cambered and metalled with gravel or rubble if such should be available. A patched job may have to do, of course, until the plantation is in full bearing.

Subsidiary roads

Subsidiary roads need only be smaller ones, with occasional places where vehicles can pass if the roads are likely to be used for wheeled transport. These roads will be required to take coffee cherry to the factory from various parts of the field, to carry mulches, manures, and spraying equipment to the fields, and to reach the labour lines. Many of them might find their best sites along the broad-cambered terrace ridges.

There will also be a private road to the owner's or the manager's house, and the site for this should be entered on the estate map before the buildings have been erected and before the lining out is done.

Roads that do not run along the contour ridges will tend to interfere with the drainage system, especially if they are taken slanting down a slope. They should then be arranged as far as is possible at the point where the contour ridges on either side begin their grade downwards and meet at their highest points, so that they may take the small amount of water collecting on the roads into the hollows above them, the roads being constructed to permit this to happen. No steeply falling ditch or drain should be constructed alongside a road unless it is carefully stepped down, and empties itself at frequent intervals into the natural drainage system.

AVAILABILITY OF IRRIGATION

Value of mean rainfalls

In a region where the rainfall is erratic, or below seventy-five to eighty inches per annum, it would be an advantage if irrigation were made available. At Lyamungu, for instance, the rainfall varies annually between extremes of 46 in. and 101 in., and also has an irregular distribution. The short

rains, which may amount to 8 in., sometimes fail, and during the long rains 80 in. may fall one year and only 30 in. the next. A figure giving the mean annual rainfall of an area, which in the case of Lyamungu is just over 60 in., does not always give a true picture of the suitability of an area for coffee production.

Irrigation by furrow

A furrow carrying water for irrigation must often travel for a considerable distance from the source of supply, and this may mean crossing someone else's land and the arrangement, if possible, of a joint financial and constructive effort. Moreover, the furrow must snake round the contours at a very gentle gradient, or be stepped down here and there in the proper manner to prevent scouring. It requires to be brought to the highest point on the land to be irrigated, and there must be an efficient series of sluice gates at the intake, and at danger points along its length, (*a*) to shut off the supply entirely and (*b*) to regulate the volume of flow with by-pass weirs where any surplus may escape in the event of a sudden storm. It is wise to have locking devices on all sluice gates so that no one but the persons responsible may interfere with them in any way.

It would be an advantage for the supply of water for irrigation to be brought to those points in the field whence the contour ridges are graded down, so that irrigation channels may be taken along the contours which have been traced for anti-erosion and moisture conservation purposes. All that is necessary is that water should trickle along small furrows between the rows of coffee without flooding, the aim being to permit the water to soak in and moisten the subsoil. Thus irrigation is turned on under careful supervision to each block in succession for as long as it is required. Further information is given in Chapter XI regarding the time of year when irrigation is best applied, and the quantities required.

Irrigation by overhead spray

Modern practice prefers a sprinkler system whereby irrigation can simulate rain, but this demands the piping of water under gravity or forced pressure to hydrants at convenient points. A great deal of sprinkler irrigation apparatus is now manufactured, for taking water from hydrants or pumping systems and connecting them in such a way that the sprinkler mechanisms may be moved about an estate. There are, for instance, lightweight aluminium pipes with special couplings. It would be best to obtain advice from manufacturing firms and irrigation engineers.

A permanent piped water supply is expensive to install, but it should last a lifetime and always be a boon. Sprinkler irrigation is not dependent on flat, contoured or graded slopes; it can be used anywhere, and the water supply might be taken from a high-level private dam, or from a tank at the highest point, to which water is pumped and stored by hydraulic ram. It will be seen in the chapter on diseases and pests that spraying programmes will be required during which there would be a saving in time and labour if water were obtainable from hydrants fixed at convenient centres. Taps should be foolproof and be of a self-closing type, or capable of being locked when not required.

Orchardists in general do not like the type of sprinkler which throws water high into the air and then permits it to fall in heavy droplets. A sprinkler which rotates and throws a fine horizontal spray is considered best.

Preparation of Nursery Sites

CHOICE OF VARIETY

Information concerning a proper site for a nursery, and all details regarding the actual rearing of plants will be found in the chapters on propagation. It is advisable when starting a plantation to consider the species or variety of coffee it might be best to grow, and to make arrangements for a supply of seed. As far as the species is concerned the environment will be the ruling factor, but a decision as to the most suitable variety is not easy to make.

Regarding Arabian coffee one hears of the high quality and repute of Blue Mountain Jamaica, of Mocha Coffee, of certain Mexican coffees, and others. Some may be true varieties, others just ecotypes of var. *arabica* or var. *bourbon* which have grown up and become adapted to their particular environments. Take them elsewhere, and they may and often do prove disappointing.

In some parts of the world the true *bourbon* variety is a strong grower, and since it is a coffee of fine quality and liquor, it would be foolish to plant any other kind in that particular region. Much depends on whether the environment is ideal for coffee. On the other hand, Bourbon coffee may not do very well and may even be rated more susceptible to diseases and pests, as it seems to be in parts of East Africa, in particular where the rainfall is short and the temperatures a little too high.

The variety *arabica* known as 'typica' in Brazil, and 'Nyasa' coffee in East Africa, seems to grow very well in Brazil, where, however, they have been fortunate to escape the *Hemileia* leaf spot disease. This variety was grown in Ceylon where the industry is said to have collapsed on account of the disease, and the same variety proved most susceptible to *Hemileia* in Uganda.

Wherever the true var. *arabica* and var. *bourbon* have struggled against adverse circumstances, 'Kent's' coffee has tended to supplant them of recent years, especially in India and East Africa. 'Kent's', therefore, appears to be a safer variety to grow, for it seems to have the required inherent stamina to resist diseases and pests up to a point, and to give better yields even in environments which would not be considered ideal for Arabian coffee. Give 'Kent's' coffee ideal conditions and it will grow superbly, give no trouble and out-yield other strains in many of the countries where it is now grown. Its out-turn, roasting, and liquoring qualities are good; almost as good as var. *bourbon*, and the author would choose 'Kent's' coffee in preference to any other if he were intending to plant coffee in a new area.

With any variety or strain of coffee, and in particular with *bourbon* and 'Kent's', it has been shown that individual trees may be outstanding. If these are selected as mother trees for seed, many of the progeny are also likely to be above the average on account of the self-fertile character of Arabian coffee. Thus it is possible, over a period of years, for a central research station to go on selecting from the progeny of these mother trees and produce what is called clonal seed. Such clonal seed procured and planted in the same locality may be considered peculiarly suited to that region. It would be unsafe to say that it will do as well elsewhere, though even this may be possible.

SOURCE OF SEED

If such a centre exists, and clonal seed is procurable in the country, one cannot do better than seek a seed supply from there, and abide by the advice of the authorities. In less fortunate circumstances it would be wise to obtain seed from a reputable plantation owner, and ask him to provide seed from old and selected trees. It may be possible to visit his place from time to time while one's own land is being cleared, and obtain his permission to observe and mark trees to choose as seed parents.

To import seed from another country is the last resort, and 'Kent's' coffee might be the best choice. Even then the advice of one's own agricultural authorities should be sought, and the supply arranged through them from some reputable source.

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Chapter IX

LINING, HOLING AND PLANTING

Lining and Spacing

The spacing depends on more than one factor, e.g., the species of coffee used, the pruning system it is desired to adopt, the type of soil and the rainfall and also to some extent on the method of planting.

In general, it has been considered best in recent years to plant Arabian coffee trees 9 ft. × 9 ft. or 10 ft. × 10 ft.; the closer spacing for single-stem trees, and the wider spacing for those with multiple stems. Robusta coffee requires a wider spacing, but it is suggested that young plants may be set at 8 ft. × 8 ft. apart in the first instance. Alternate rows could then be allowed to grow with a single stem with the object of cutting them out after they had borne their first big crop. The remaining robusta trees would then be 16 ft. × 16 ft. apart, not too wide for multiple-stem pruning of any kind; in fact a few more trees might need cutting out in future to increase the spacing, if the natural branching habit of pruning was adopted for the *nganda* variety.

Liberian coffee might be treated in much the same way, arranging for a spacing of 10 ft. × 10 ft. in the beginning. The same spacing might also be allowed for excelsa trees if ever these were planted, since cutting out could proceed as required until an ultimate distance apart of 40 ft. was reached.

Such distances will allow for shade trees to be planted within the rows of coffee at suitable spacings, and it will be necessary to line out for shade tree planting at the same time. Although spacings were closer in East Africa a few decades ago, Arabian trees are not now planted closer than 9 ft. apart, or more than 10 ft. whereas robusta is given a 10- or 15-ft. spacing for multiple-stemmed trees.[2] In India,[1] Arabian coffee trees with single stems are still planted 6 ft. × 6 ft. apart, which appears to be a frequent spacing among other planting regions of the world. Single-stem 'Kent's' coffee tends to close up and overlap at Lyamungu at 4 years old when it is planted 9 ft. × 9 ft. apart.

SQUARE PLANTING

The old practice of planting orchard trees in straight lines on a geometrical pattern, so that no matter where the eye looked a straight line would be seen, is being discontinued. It looks nice, it gives each plant a square deal in so far as space above and below ground is concerned, and it allows cultivation to be practised each way between the rows. It is, perhaps, ideal on level ground if ever this could be found, and because it simplifies the task of keeping records it will generally be found on experimental plantings. (*See* Table.)

Square or triangular planting is not so easy to mark out on undulating land, neither does it look so workmanlike in a modern planter's view as the curving rows which follow contour planting. When all is said and done it does not matter how coffee is planted provided the trees are the *correct average*

SQUARE PLANTING.

NUMBER OF PLANTS PER ACRE

Distance apart in feet	*Number of plants per acre*
6 × 6	1,210
8 × 8	680
9 × 9	537
10 × 10	435
12 × 12	302
15 × 15	193
16 × 16	170
20 × 20	108
30 × 30	48
40 × 40	27

distance apart and that they are in rows in one direction to facilitate movement. With contour planting the rows must follow the contours, and since the width between the curving contour ridge terraces is uneven, there will be places where some rows must come to an end because of the narrowing field.

Rows planted along the contour force subsequent cultivation to be carried out along the contour, which is a good thing during the few years while cultivation is necessary. In a few years' time cultivation must stop, as will be seen in the chapter on maintenance, and then all that will be necessary will be to keep the soil under a mulch. All the other operations on an estate such as carting, weeding, irrigating and so on, are best accomplished along the contour between the curving rows of coffee, and not up- and downhill. Enough has been said to show that the spacing and task of lining out depends a good deal on the method the planter chooses to adopt.

Provided the trees have room for growth up to an adult age, spacing may be a little closer in a high rainfall area. When rainfall is short the tendency should be to plant trees farther apart, because they will need a wider area of subsoil from which to draw their moisture supply during dry periods of weather. During the drier months close-planted trees in a region of short rainfall may create a moisture deficit in the subsoil which is dangerously near the wilting point if irrigation is not available. In the author's opinion no coffee should be planted closer than ten feet apart in a region where the rainfall is less than fifty inches a year, especially if the rainfall is not evenly spread. If the soil is at all sandy, or on the light side and thus less retentive of moisture, then this should clinch the matter and weigh in favour of a wider spacing.

TOOLS FOR LINING

At each spacing it will be necessary to drive a stake. Hence mallets will be required with quantities of strong pointed stakes of some local hard-wood. The stakes used for the coffee may be half the length of those used for the shade tree spacings. The wood must be durable because the stakes may be

required to last for a period of about a year, in spite of tropical decay and white ants. The foreman who does the lining out will need a good eye and careful judgement. He will require several helpers, and a chain a hundred feet long clearly marked with tags at the required planting distances.

Some people use a rope, but rope contracts or expands in length to a considerable degree in accordance with the moisture it takes up, as everyone knows who has ever lived in a tent.

PROCEDURE

For square planting it is necessary to obtain, in the beginning, two straight lines of stakes crossing at an accurate right angle. Using these base lines, and working from them, the men with the chain fix distant markers, or sighting stakes at multiple spacings, so that single spacings may be filled in afterwards between them. In other words, the large squares marked out in the beginning may be filled in afterwards by the smaller squares. If there is need for haste then another gang can follow and carry out this second task, using chains or measuring rods; the more stakes that have been set in place, the easier it is to sight the lines. It is easier to correct inaccuracies in sighting if the larger squares are staked out first, for their corner stakes become master ones with which the smaller spacings must agree. With good sightsmen directing the men holding the stakes, a great deal of measuring within the larger squares can be dispensed with.

With square planting the roads are usually arranged to correspond and enclose blocks of trees of equal number. In other words, the roads must also cross at right angles, and the base lines for measurement should be the roads where they cross at one corner of a block (*see* Fig. 16).

CONTOUR PLANTING

In contour planting the base lines are the original trace lines, i.e., for anti-erosion ridges. The first line of stakes are measured along these, or at a measured distance above, whichever is decided upon, since some other use may be made of the tops of the ridges. Successive lines of stakes at the proper distances apart but not necessarily at right angles or diagonally arranged, are then placed to take the curves of the first line, until they begin to meet with the contour ridge above (*see* Fig. 17). It will often be found that some of the spacings become diagonal. A man who is used to the old rule of thumb square planting will shake his head and look upon this as a mess, but from a distance there is nothing finer or more heartening than to see undulating and hilly country planted on the contour. It looks and is more natural, and, in fact, the task of lining out is much simpler. Working upwards from each base line, all that is necessary is to get the lines spaced evenly apart, and the stakes at the correct distance from each other in the lines.

HOLING

SIZE OF HOLES

Coffee is often planted in very small holes, or perhaps the seed is sown at stake in a ploughed field. For many years in East Africa and India, a four-

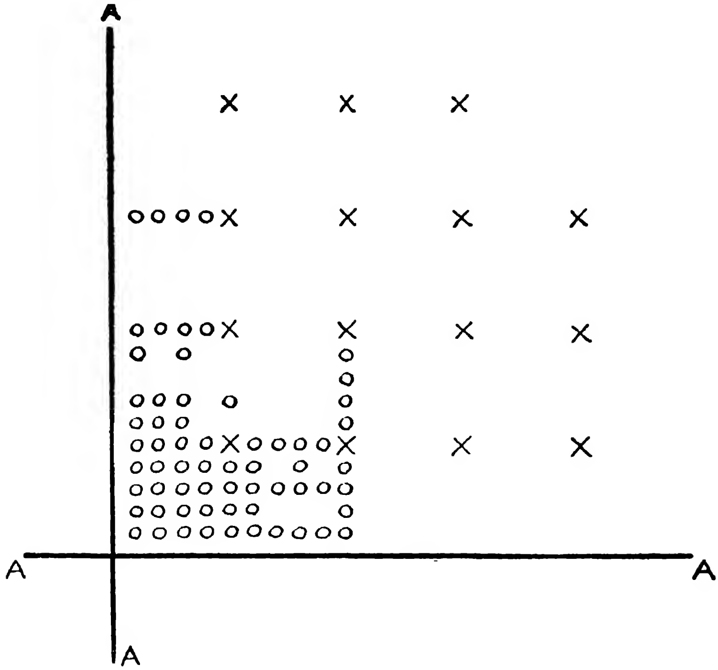


FIG. 16.—AA: Base lines; XX: Shade trees and master squares or stakes; OO: Filling in larger squares with stakes for coffee.

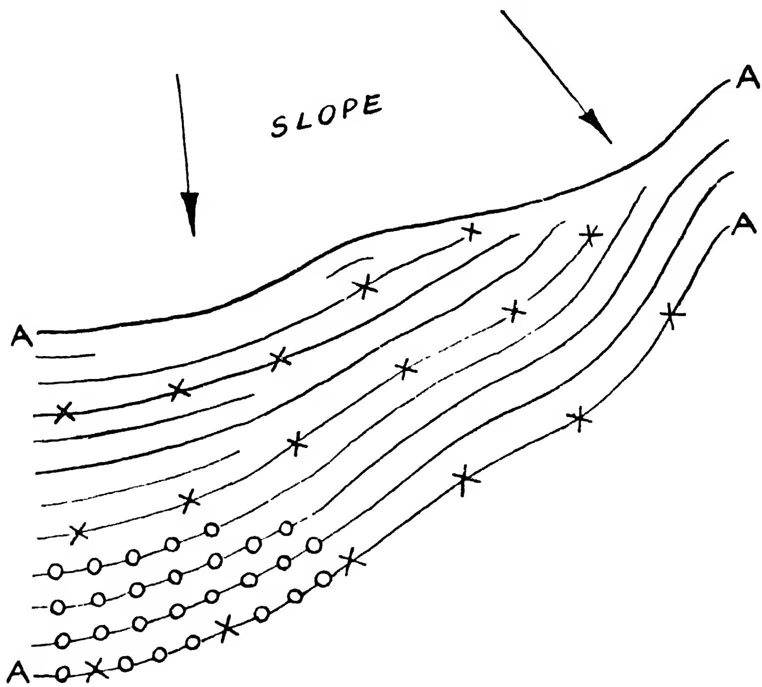


FIG. 17.—AA: Contour ridge trace lines; XX: Shade tree spacings; OO: Coffee spacings.

gallon kerosene oil tin has been the measure for the size of a hole. This being so, the results of an experiment in Kenya[4] are enlightening, and help to prove the horticultural teaching in the days of our grandfathers. Coffee was planted in holes of various sizes, and a little manure was mixed with the soil at the time of planting. The results for two tests are given below, one at the Scott Agricultural Laboratories and the other at Kitale. They are records for six years' duration, with an average yield in lb. of cherry per tree.

SCOTT AGRICULTURAL LABORATORIES

Size of hole Width and depth ft.	*Average yield of cherry per tree lb.*
3 × 3	26·28
2 × 2	23·63
1½ × 1½	24·80
1 × 1	23·39
½ × ½	20·63

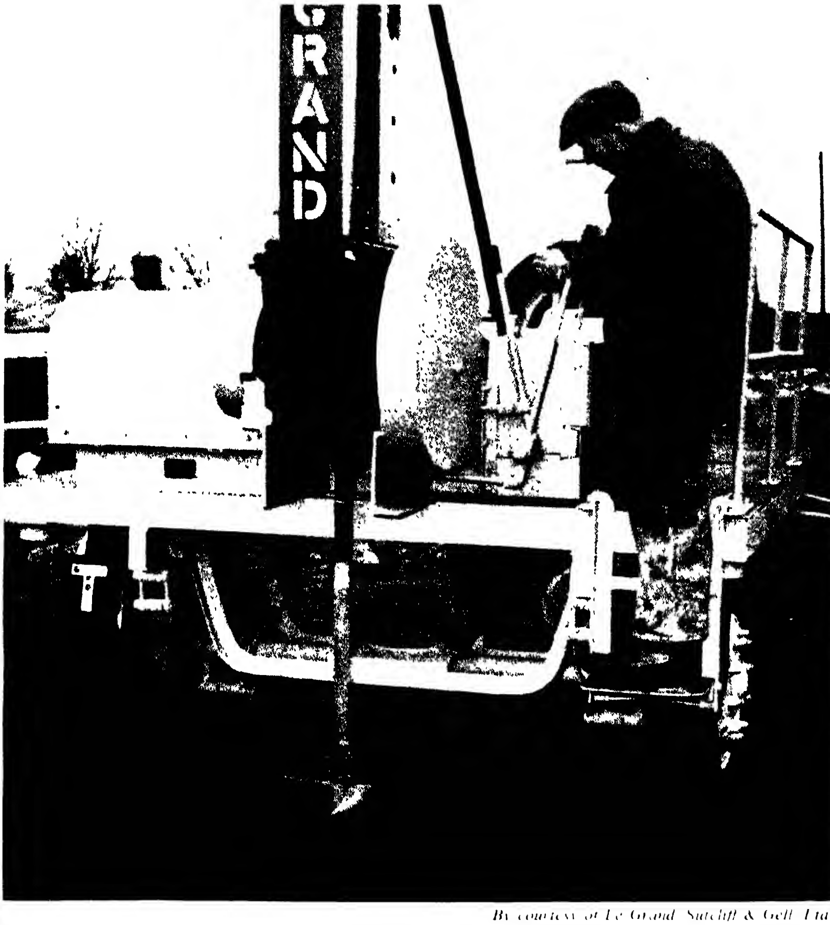
KITALE EXPERIMENT STATION

Size of hole Width and depth ft.	*Average yield of cherry per tree lb.*
3 × 3	24·0
2½ × 2½	24·0
2 × 2	23·3
1½ × 1½	22·2
1 × 1	21·9

Though a mathematical examination of these results does not indicate enough difference between the treatments to be significant, yet the trend of increasing yields corresponding with the increased size of the planting hole is clear to see. In the United Kingdom no one would plant a fruit tree in a hole less than two feet six inches in diameter and two feet deep, despite the high cost of labour. It is only natural that a young tree will grow healthier if it is given such extra care and a softened, aerated and weathered soil round its roots.

A good start means the building up of a stouter stem, a stronger frame, and a better root system before the trees begin to bear, and this gives them a better chance to come through the first bumper crop with less disease, die-back and empty cherry ('buni') which accompany exhaustion.

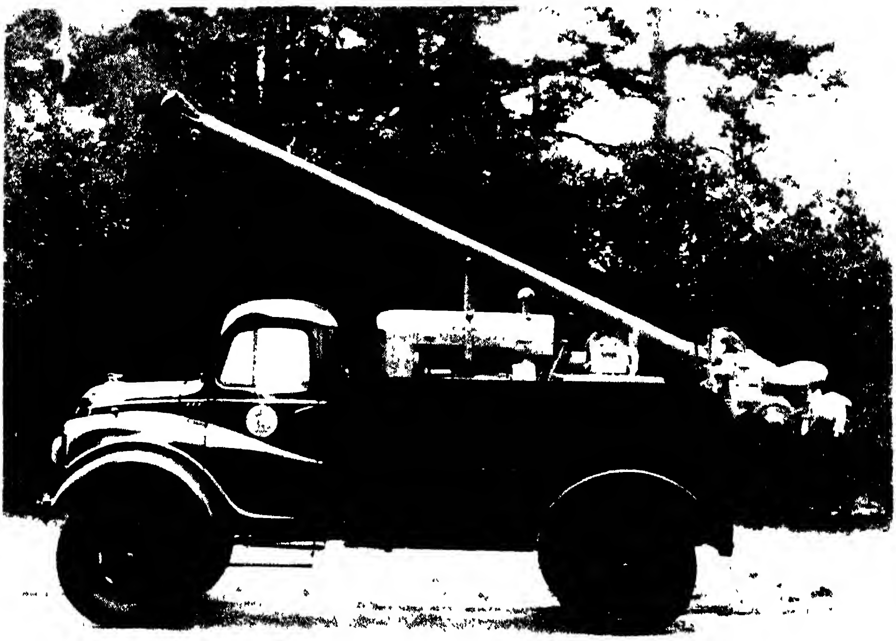
The ultimate decision as to how big a hole should be is in the hands of the planter, who will naturally consider his purse. The difference in yield may not be great as the years go by between trees planted in 2 × 2 ft. holes or 3 × 3 ft. ones. As the roots of coffee penetrate and wander farther into the surrounding soil the trees have a habit of evening up their responses to earlier treatments, so for big-scale planting a hole 2 ft. × 2 ft. in size might be found large enough, and even a hole 1½ ft. × 1½ ft. can be considered if the coffee plant is small, i.e., with six pairs of leaves.



By courtesy of Le Grand, Sutcliff & Gell, Ltd.

The Le Grand soil borer. This recently-evolved machine bores holes 9 in. to 22 in. diameter to a depth of 16 ft.

PLATE XXXI



By courtesy of the [illegible] Co.

Earth-boring machine

PLATE XXXII

DIGGING THE HOLES

The holes are marked out with a spade before the stake is pulled out, and the soil is then thrown to one side below, and not above the hole if there is a slope. There should be some system agreed beforehand, so that the soil is neatly aligned on the same side in each case, with the top soil to the left and the subsoil to the right. Then, when the time comes for refilling, the top soil will be readily available to throw in first. When a hole has been dug to full size, the bottom should be loosened and the stake replaced loosely in the hole. It does not really matter if the holes be square or round provided they are the right depth.

MECHANICAL HOLE DIGGING

For some years it has been possible to buy mechanical mobile auger drilling apparatus for digging holes for posts. Only recently, however, has such apparatus been designed to drill larger holes up to twenty-two and thirty inches in diameter.

What a boon one of these machines would be to a planter about to hole out a 250-acre estate at 9 ft. × 9 ft., totalling 134,250 holes which have hitherto been dug by hand. Should anyone invest in one of these machines one can imagine the queue of those waiting to hire it for their own estate. The provision of such a machine is possible by co-operation, i.e., by a Planters' Association hiring out such a machine to its members.

TIME FOR DIGGING

It would appear that an advantage is gained by digging the holes some while before the planting is carried out. Perhaps the soil and the sides of the hole at depth become weathered, and more fertile, but it is most likely that water collects and stands in the holes during showers of rain, and the sub-soil in the immediate vicinity is supplied with extra moisture. It is amazing what a sufficiency of moisture will do, and how much more valuable it is than manure.

The following table of results from a planting experiment at Lyamungu is worth discussing.[3] Firstly, it will be noticed that there were no yields in the years 1944 and 1946 owing to crop failures. Secondly, it is astounding that the 'no holing' treatment should have given, right from the start, better returns than plants planted in holes dug and refilled one month before planting. In regard to the 'no holing' treatment, the roots of the young coffee plants were placed in the ground with the least possible disturbance to the soil.

Is this a question of moisture again? The plants in the holes dug for three months and then filled one month before planting might have had time to collect rain, and be thoroughly wetted before the refilling. Anyhow, it seems to have been proved that digging the holes at least three months before planting brings its reward in higher yields even ten years later. It is obvious that the young trees received so much benefit that they grew stronger roots and frames and were thus capable of bearing better crops in later years without so much exhaustion.

YIELDS IN CWT. CLEAN COFFEE PER ACRE.

Treatments	*1938*	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*Average yield*
(1) No holing.	6·66	2·11	5·08	11·94	5·04	17·11	—	24·86	—	22·20	9·81
(2) Holed 3 months and filled 1 month before planting.	7·90	1·13	6·85	11·67	4·98	17·42	—	27·73	—	25·77	10·54
(3) Holed and refilled 1 month before planting.	5·65	1·43	5·35	10·76	3·89	11·87	—	27·55	—	22·84	9·30
Treatment (2), sub-soiled without compost.	7·78	1·17	6·51	12·30	3·81	14·77	—	26·14	—	24·21	10·02
Ditto with compost.	8·29	0·82	5·83	11·72	4·85	14·54	—	27·07	—	22·44	9·91
Treatment (3), sub-soiled without compost.	6·11	1·53	5·46	11·43	3·70	13·24	—	25·19	—	23·71	9·34
Ditto with compost.	6·27	1·48	4·26	11·32	4·88	12·74	—	26·39	—	19·15	8·96

Filling the holes one month before planting is, of course, so that the soil should have time to settle down. A sinking soil often means that a young plant is set too deeply.

This raises another point, however, since it is against usual horticultural practice to refill a hole before planting. It would be all very well to refill a hole with soil if seeds were to be sown at stake, but if plants have to be set out in the field in holes that have been refilled, then this means the use of a trowel or a spade, and digging out enough space again in which to spread the roots. There is a grave danger that the secondary hole will not be made large enough, and that the roots of the young coffee trees will be crumpled and cramped. In true horticultural practice, holes are filled in as planting is done, while ensuring that the roots of the plant are spread out to their full and natural extent. The soil is well firmed during the process. It should be a careful job rather than a hasty one, and carried out by two men; one holding the plant and spreading out its roots, while the other fills in the soil. If the old stake is placed horizontally across the centre of the hole, the collar of the young plant may be held against it to give guidance as to the planting depth. The author has seen both practices, and has planted many thousands of plants in the old horticultural way to their advantage. There is a greater danger from crumpled roots when planting in re-opened holes than there is from deep planting, on account of soil settlement when the holes are filled at

the time of planting. Deep planting then means carelessness in positioning, or in firming the soil, and, of course, carelessness in supervision. If ever there is a task which should be well supervised, planting is that one.

Refilling before planting may often be practised nowadays, but it is a practice that has grown up among non-horticulturalists. An old gardener would ask, why dig holes and fill them twice? However, it is up to the planter to make his choice of the method used. Experiment has shown that coffee benefits if the holes are dug and left open for several months before planting.

THE RIGHT DEPTH FOR PLANTING

Experiment and experience have shown that coffee is harmed if it is planted at a lower level in the soil than it grew in the nursery. Coffee is not alone in this respect. It is not something new, despite the fact that experiments have been delayed until the last few decades in proving a hundred years of practical teaching true. The surface roots of some plants have a greater depth of penetration than others.

In the great class of plants known as dicotyledons, which are those that unfold two leaves known as cotyledons from within the seed, the point on the stem from which these first leaves spring is known as the collar. During transplanting, tiny seedlings may be planted in the soil up to their cotyledons, but not beyond; in other words, the collar may be at, or a little above ground level but never below. Most dicotyledon seedling plants suffer if they are planted too deeply, and only a few can rearrange, or adjust themselves to the right depth. This should be common knowledge, and yet, in East Africa and elsewhere, many thousands of coffee plants have been set too deeply in the soil.

BALL PLANTING

The term 'ball planting' is liable to misconception. Many untrained people are led to believe that ball planting means digging out plants from a nursery when the soil is moist, with as much soil as possible round the roots, and then crushing the soil into a round compact ball the size of a cannon-ball.

It would be better if the term 'ball planting' were never used, for it was never meant to be conceived as such. It means nothing more than carefully digging the plant from the nursery, and lifting it out and laying it in a basket with as much soil adhering to the roots as possible. In the same way it is handled carefully and planted with the soil still adhering, albeit much of it will drop away. Never, on any account, must the soil be pressed or firmed to the plant's roots in any way. It often happens that all the soil falls away, leaving the roots bare; this does not matter very much if the plants are kept shaded, planted carefully without delay, watered in and shaded in the field. They may tend to wilt a little more than those which had a fair amount of soil still adhering to their roots.

STUMP PLANTING

One may stump back a raspberry cane, or an apple maiden, and many plants that are deciduous are treated in this way before planting, though it is not generally considered a good thing to stump back an evergreen. Coffee is

an evergreen, and the planting of stumps such as has been practised widely in Kenya, is undoubtedly a get-rich-quick method of planting. In fact, in the author's opinion it is an evil practice, and one fast dying out.

To begin with, the plants are grown at the usual close spacing in the nursery until they have made branches. They become so tightly interlaced that they produce leggy, yellowing specimens, leafless except at their extremities. When the stems above the collar are about the thickness of a pencil or more, they are all ruthlessly decapitated, leaving stumps about six inches long. These are then dug up, the soil shaken free and the roots cut short. In this manner are they made ready for planting—so easy to set with a trowel in a refilled hole.

The stumps must make new feeding roots and new shoots from material already weakened by overcrowding, in fact, it may be the relief from that overcrowding which gives them the impetus to grow. Be this as it may, the stumps go through a spell during which a crisis is passed and they either live or die. It is surprising that a large percentage live, and in good time produce trees, but they must feel the shock and that hesitation on the brink of failure all their lives; their yields doubtless reflect such rough treatment. Stump planting is not a practice to recommend.

THE SIZE OF THE SEEDLING PLANT

Many planters have planted, and still plant, seedlings of mature size without stumping; plants that have made a number of primary branches. There would be nothing against this method, perhaps, if only the seedlings were spaced sufficiently far apart in the nursery, and this would be uneconomic. To permit overcrowding, and allow them to grow leggy stems with spindly branches poorly supplied with leaves is surely wrong. The plants are weakened and overgrown, and since they are too close together it is impossible to move them with enough soil, and with the care that is necessary for a plant of this size.

To prevent too great a shock, plants with branches require to be moved with their soil intact—a massive lump of earth at least a foot square—though this is never done. People imagine that all sorts of liberties may be taken with plants and crops provided they are situated within the tropics. To many the tropics are pictured as having fertile soils, steamy jungles and a riot of vigorous growths which are hard to keep in check. Crops are supposed to grow like weeds, and all manner of things can be done with them that one would not dream of doing in a temperate country. Such people are surprised to learn that these things are not true, but the belief lingers and is difficult to eradicate.

It is best to transplant seedlings when they are very young. Doubtless it is better to transplant germinated seedlings in the nursery before the cotyledons have unfolded and thrown off their seed shells. Undoubtedly it is best to set plants in the field before the stems have begun to branch, when, in fact, they have made no more than six pairs of leaves. The roots can be moved with more soil attaching to them, since they have not grown so large and are thus not so greatly disturbed. The plants soon 'catch hold' in the field and wilt very little if they are shaded for a day or two. There is only one disadvantage. They are more tender and thus more subject to the hazards of the open field—principally to cut worm attack, to mole crickets and leaf-eating grasshoppers.

The many advantages, however, outweigh this one fear, and if the rows are constantly inspected it is neither difficult nor onerous to pop in supplies in good time in the few vacancies that occur.

PLANT SELECTION IN THE NURSERY

While seedlings are being raised for planting, a keen watch should be kept for any plant that is not true to form, or is in any way a deformity or a weakling. These should be pulled out at once and thrown away. Sometimes there are plants with leaves in threes instead of pairs. One or two may be heavily bronzed, almost red in colour, while others may have small narrow leaves and spindly growth. Their destruction will give more room for the healthy ones to grow, and avoid planting them by mistake.

While planting them there is a last opportunity to discard weakling plants, and a trial was carried out at Lyamungu in Tanganyika to discover whether there was any difference over a period of years among bushes resulting from seedlings of various kinds. The results are summarized in the following table and the yields are given in cwt. of clean coffee per acre.

SEEDLING SELECTION TEST.

Type of seedling	*Average yield of 9 years' cropping, 1938–46*
Average	4·71
Poor tops and poor roots	4·23
Good tops and poor roots	4·60
Poor tops and good roots	4·36
Good tops and good roots	5·24
Tops cut back	4·20

Although the results are mathematically not significant, there is sufficient to indicate that the selection of good nursery plants is a sound practice, and that the best and most vigorous young plants will give the best yields over a period of years, even when they are eleven and twelve years old.

PLANTING TESTS WITH SEEDLING STOCK

A table is inserted showing the yields recorded for ten years after various planting methods had been initiated. The average yields will be considered satisfactory bearing in mind that the crops failed in 1944 and 1946.

The astonishing point to notice in regard to this test is the marked residual effect of the original treatments even after a period of ten years, and the way in which the results bear out one's beliefs. The worst returns are given by the seedling plants which have been deep-planted six inches below their collars, and the best returns are those from the seedlings planted at the proper level in the soil. It may be noticed, however, that there is very little difference between those planted with earth attaching to their roots, or those with their roots bare. This is very important, for it means that no one need bother too much about the soil remaining attached to the roots.

LYAMUNGU, TANGANYIKA TERRITORY:

YIELDS IN CWT. CLEAN COFFEE PER ACRE

Planting method	*1938*	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*Average yield 10 years*
Deep with earth attached	6·22	1·26	4·97	11·20	3·76	14·36	—	25·83	—	22·30	9·27
At nursery level with earth attached	7·85	1·68	6·35	12·03	5·80	15·10	—	26·81	—	24·07	10·28
Deep with roots bare	6·50	1·10	5·02	10·54	3·87	13·37	—	24·85	—	21·38	8·89
At nursery level with roots bare	7·24	1·49	5·32	12·56	4·36	15·29	—	28·14	—	23·86	10·32

PLANTING OF ROOTED CUTTINGS

Rooted cuttings should not be planted until they have been in their fibre pots or wicker baskets sufficiently long to have made good roots after their removal from the frames. They should have been hardened off by a period of several months out of doors under light shade. If they are in this condition and ready to plant, then it is better to plant them in the field without delay and before their containers begin to rot or become filled with curling roots.

PREPARATION FOR PLANTING

It has not been proved with any degree of certainty that coffee is benefited in any way by adding manure in the hole at planting time; in fact, Arabian coffee appears to be peculiarly unresponsive to manuring at most times provided the soil is fertile in the first place. On the other hand it can do no harm to add manure, and it may in some circumstances help the tree to make a better start. If manure is added, the quantity should not be more than a couple of shovelfuls of well-decayed compost or farmyard manure placed at the bottom of the hole and not in contact with the roots of the coffee. Chemical fertilizers have no application or use at this time; in fact, they may do harm, and if organic manures are used it will be necessary to place them in position ahead of planting. When this is done the original stakes in the holes will require to be pulled out and laid nearby. If the holes have been refilled before planting, then the manure should have been placed in position then, and they will have to be partially reopened ahead of planting.

PLANTING COFFEE

There must be little delay in setting the plants out in the field after they have been lifted from the nursery. Everything must go like clockwork, and there must be no bottlenecks caused by supplying plants too quickly to the field, or long waits because the holes have not been reopened in time. The labour

gangs must know exactly what they are required to do, and there must be liaison between the nursery gang and those planting in the field. Two men should do the planting at each row, one to shovel the earth and fix the shade, the other to hold the plant, to spread the roots and firm the soil. Meanwhile there are those whose task it is to drop the required amount of temporary shade at each hole, ahead of planting, and others who must follow with a water-cart and a watering-can. The plants need just enough water to settle them in, even though the weather be dull at the time, for the evaporation of moisture from the soil will cool the air round the plants and help to prevent wilting.

The nursery should be well watered the previous day if the soil has not been thoroughly moistened by recent rain. The plants must be lifted by inserting a spade, or better still a fork, very deeply, to lever the soil gently upwards. The plants need separating and laying carefully on their sides in flat boxes or baskets, without worrying too much if the soil falls away. It is helpful to know that bare root planting has no evil consequences, since it is awkward to carry a great deal of soil with the seedlings, and the work will proceed with greater speed without it.

All the boxes or baskets should be kept covered with material such as green banana leaves or a wet sack, and it is sufficient to carry fifty plants at a time. Even less would be better if the distance to the field is not great. An opportunity is given during lifting to throw out any malformed, weakly and diseased plants that are not up to the standard, or obviously do not conform to type, and a stream of carriers should be passing to and from the field. Any bulking of supplies of plants for lorry transport should be avoided as much as possible on account of the delay that occurs while making up the load, though this may not be avoidable when the field is distant. Baskets or tiers of boxes on a loaded lorry may be sprayed with a mist sprayer during bursts of sunshine to keep the plants cool.

TIME FOR PLANTING

Planting may begin when the big rains have started and the soil is everywhere moist. The soil should not be wet, and planting should cease during heavy showers and be resumed when the soil is no longer sticky. If there are intervening days of hot sunshine it is then better to plant during the evening, when the strength of the sun has waned, so that the plants have the cool of the night and the early morning to follow. Dull and calm weather is at all times preferable for planting, when showers may be expected at any time. It is an anxious and busy time. The men who actually plant must be taught to have a pride in their task, and be selected for their patience, their honesty and their delicate handling of the young plants.

REDUCTION OF FOLIAGE

Some people believe in cutting away half the leafage of each plant to reduce the transpiration and the risk of wilting. This should be unnecessary if the planting weather is good, as it should be before planting is started. Hormone substances are produced in the leaves to promote rooting, and the leaves also manufacture food of the right kind to feed the growing roots. A reduction of leafage may thus upset the balance in another way and should be avoided.

TEMPORARY SHADE

As soon as coffee has been planted it is necessary to shade the young plants for about a week, until their roots have begun to catch hold. This is done by pushing three cut lengths of palm leaf (or some other stiff vegetation with finely divided leaves) into the soil to form a cone-shaped shade or shelter over each plant about one foot six inches high. The men planting will often twist or tie some of the leaf fronds together to stiffen the support and prevent the shade being blown away by wind.

This temporary shade is just as necessary at high altitudes where permanent shade will be unnecessary, as it is at lower elevations. It will give shelter from cold winds and cold night temperatures while the young plants are establishing themselves, and also from any hot afternoon sunshine which might cause wilting. The shade should be withdrawn at the end of a week.

SUPPLIES

A newly-planted area should be examined twice a week for the first fortnight, once a week to complete the month, and once a month for the next six months. Any vacancies caused by the death of a plant should be filled immediately, and if they occur a month late it is best to use pot plants kept in reserve for this purpose in the nursery. The owner or the manager should keep himself informed of the reason for the failures, so that he may take steps to safeguard the remainder of his plants from any avoidable cause.

CUT WORMS AND MOLE CRICKETS

Fair protection may be obtained from cut worms and mole crickets by fixing short tubes of tin round the stems of the young plants, the base of the tubes being pushed a half-inch into the ground. The tubes may be improvised on the estate by cutting small squares of tin and then bending them round a rod, leaving gaps which may be closed by pressing the edges together after they have been placed in position round the plants. Care must be taken to collect these tubes when the plants have grown beyond the possibility of harm.

PLANTING SHADE TREES

The same procedure should be adopted for planting the shade trees as has been followed for the coffee, if nursery plants are to be set out in the field. It is not always possible to line and hole out in readiness for planting the shade trees a year ahead of the coffee, but if this were possible it would be ideal. The shade trees should not be planted any earlier than a year in advance, otherwise the young coffee plants may feel the root competition before they are able to draw moisture supplies from a sufficient depth and area of the subsoil.

Seeds of some shade trees may be sown in the field at stake, in which case the holes must be filled and the soil firmed beforehand, and several seeds sown at each stake with the object of thinning the seedlings gradually to one at each spacing, as they grow big enough to become established and safe from the normal hazards.

Other shade trees such as species of *Erythrina*, and fig, may be planted as

pole cuttings, in which case narrow and deeper holes may be dug as though they were wanted for posts, and the cuttings planted at the beginning of the rains and well firmed in an upright position. They will sprout principally at the top, and any side-shoots should be rubbed off from time to time.

RECORDING PLANTINGS

From the very beginning a plan of the estate should be carefully drawn to scale, and as the successive tasks such as roads, drains, terrace ridging and buildings are accomplished, these should all appear on the plan. The fields of coffee might be referred to as numbered blocks, their shapes and acreages noted, and the number of plants planted in each block. Thenceforward it will be possible to compute the annual and average yields per block, per acre, or per tree, and compare the yields from different parts of the estate. Various treatments can be applied and the results be known, compared and verified. If the average yield per tree is known, then those that outyield this average may be noted as seed bearers. If blocks of coffee of different origin are planted, the yields can be compared and be useful to record as the years speed by. All sorts of valuable information can be obtained from proper recording, upon which action may be taken to benefit the estate and increase the yields. The planter who does not keep records in this fashion loses half the joy of life.

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Chapter X

PRUNING COFFEE

ARABIAN COFFEE

SINGLE-STEM PRUNING

ANY thought of training robusta coffee permanently with a single stem should be dispensed with immediately, though this has been attempted in the past in some countries. Many may say that the single-stem pruning of Arabian coffee is also now out of date, because research at the Lyamungu Experiment Station in Tanganyika Territory, and elsewhere, appears to have proved that yields are heavier when a multiple-stem system is used over a period of years. For this reason most planters in East Africa have now adopted the multiple-stem method, and they may scorn any idea of reverting to the older system. That they may be wrong in adopting multiple-stem growth in some localities the author will try to prove, for like many another swing from one practice to another it is possible to swing too far, to believe in extremes, and to ignore the odd and unusual cases where a middle course or the older method is still desirable.

Firstly it is wise to review the older method to see how it was practised, and to describe what it meant. The term 'single stem' almost explains itself, since the tree is permitted one main stem, and this is allowed to grow four feet six inches or five feet tall before it is topped and kept at this height. The branches or secondary growths, usually miscalled 'primaries', bear what are called 'secondaries' and even 'tertiaries' in course of time, and these are pruned away or left as the case may be, so that they are all spaced evenly, and sufficiently far apart to allow light and air to penetrate between the foliage. The lower branches are sacrificed if they bend down and touch the ground, the weaker wood is cut away near the main stem to allow air to circulate up the centre, and the aim is at creating a plentiful supply of healthy leafy wood on which the next season's crop is generally borne.

At the same time every effort is made to safeguard the strength of the primary branches because the tendency is for them to weaken with each successive crop, and to lengthen their bearing tips too far from the main stem. If they are permitted to do this they grow spindly and droop. Successive prunings aim at cutting back the primaries to strong secondaries, thus arranging for the secondaries to replace the primaries that have grown too spindly. Meanwhile all the sucker growths that spring from the main stem are pinched away at regular de-suckering cycles which should be sufficiently frequent to prevent these growths being more than a few inches long.

It will be seen at once that the selection and thinning of secondary growths becomes somewhat complicated, necessitating the use of intelligent and trained pruners who are not always to be found among the indigenous labour force. It is costly, too, since the pruning must be done care-

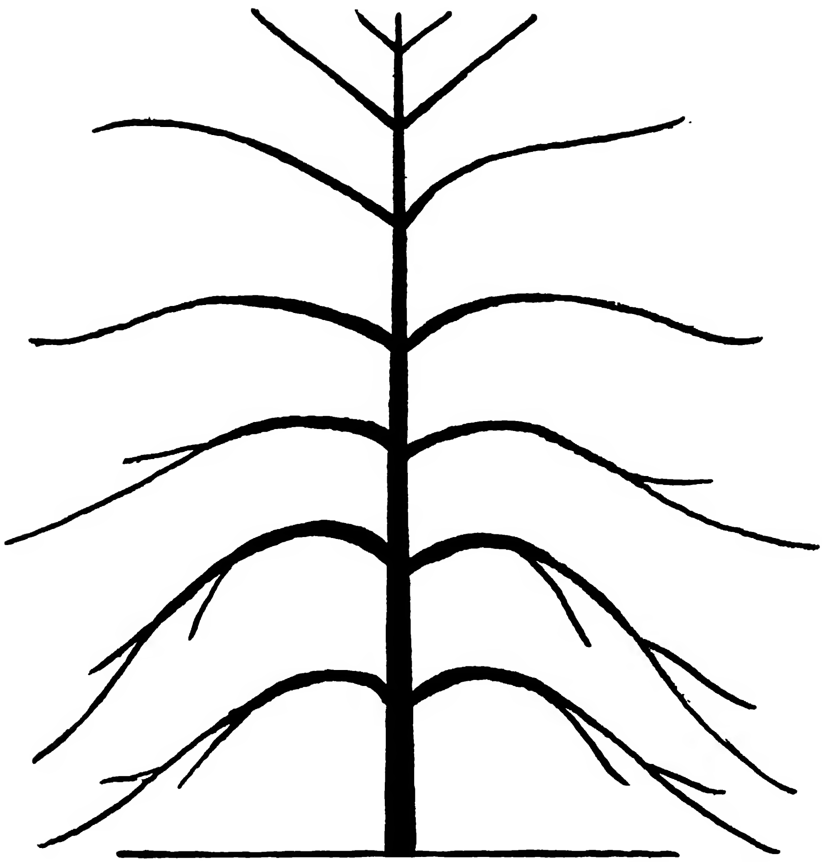


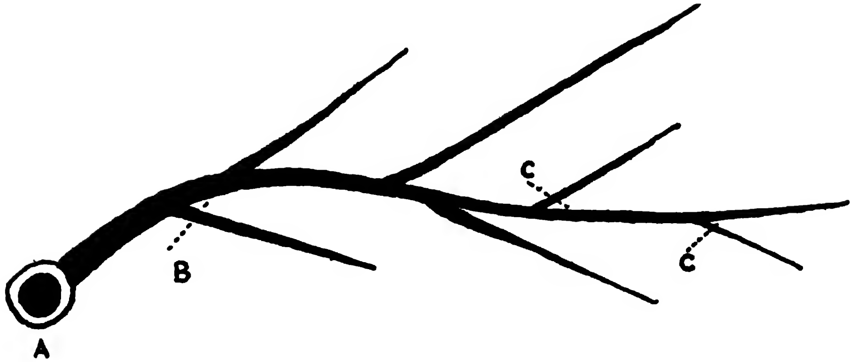
FIG. 18.—The branching habit of a four-year-old single-stemmed tree.

fully and thoroughly and an adult tree may take as long as ten minutes to prune.

A large proportion of the world's Arabian coffee is grown under conditions that are not ideal, because the temperatures are either too high, or the rainfalls are deficient or unevenly distributed throughout the year. Arabian coffee then tends to grow too fast and bear too early. For the same reasons, the adult trees produce too much growth when they are pruned, and the more the knife is used the more prolific is the next flush of growth.

Coupled with these symptoms the trees flush into flower at odd times, they bear green berries of all sizes and ripe fruit at the same time in season, all upon the young wood. Such a heavy call for sustenance overtaxes the power of the leaves to manufacture sufficient food, so they weaken, turn yellow and fall. The overcrowded branches then begin to die-back from the tips before the fruit has properly ripened and filled out with mature beans. It is at such times, when the health of the trees is at a low ebb, that pests such as Thrips, Antestia, and scale prosper, and diseases such as rusts and leaf spots can be so damaging.

If over-bearing and a weakened state coincide with either pest or disease



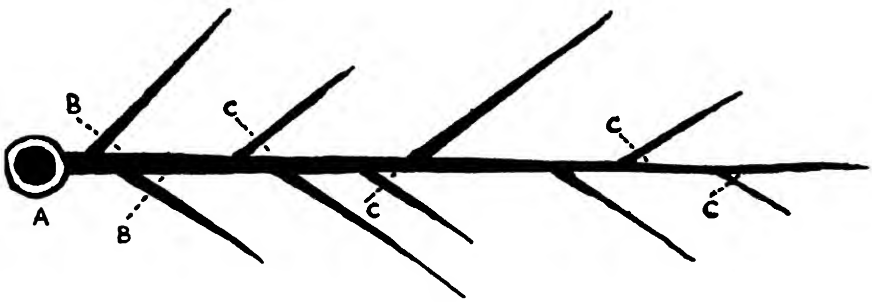


FIG. 19.—Orthodox methods of pruning primaries on single-stem coffee. A—Main stem in cross section. B—Secondaries too near main stem. C—Surplus secondaries to be pruned away.

attack, and also with a period of dry weather, then disaster follows. Die-back is severe and many of the lower primaries are lost. At the same time a big proportion of the crop is lost through immaturity; the bean is small and a great deal of 'light' coffee is harvested. Trees in such a state have, of course, been wrecked, since they cannot replace their branches if they have died-back to the main stem. At the very best a severe pruning must follow, and two seasons must pass before the trees have grown new bearing wood, and have regained sufficient strength to mature another crop, when the whole cycle of events may be repeated. For these reasons triennial cropping has been experienced in the past in countries such as Uganda, and in parts of Kenya and Tanganyika where the single-stem method of pruning has been practised. Planters dreaded bumper crops because of the exhaustion which invariably followed, and they tried the costly practice of 'stripping' to reduce the fruit on the branches while the berries were quite small.

Arabian coffee has often been planted far too closely, with the trees no more than six feet apart. By the time they are five and six years old the laterals begin to touch, and the lower branches then suffer from want of light. Spindly growth is the result, die-back and exhaustion are frequent, and the trees soon tend to lose their lower branches and grow like umbrellas, with only a top growth of drooping branches. Stumping must then be attempted in the hope that suckers may grow up from the rootstocks to form new main stems. There

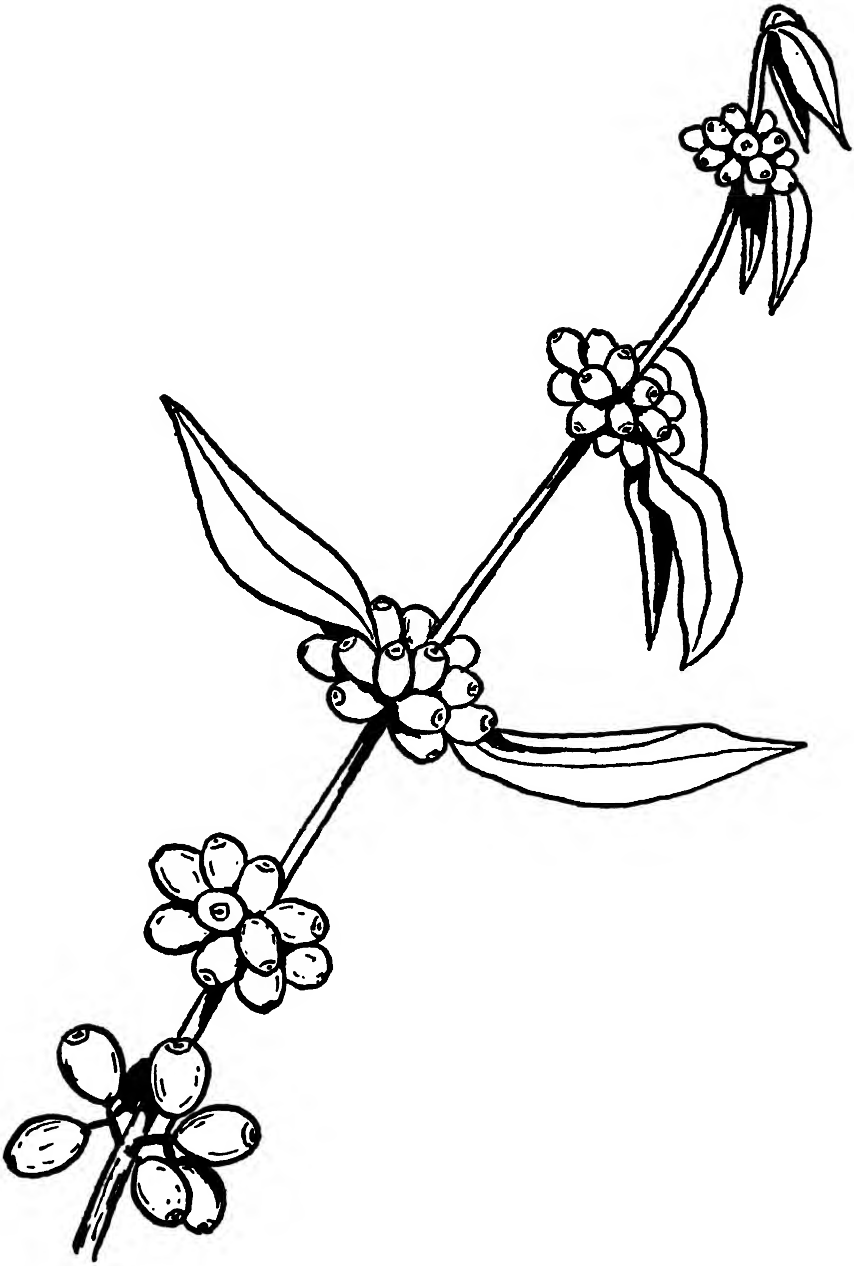


FIG. 20.—Diagram showing climatic over-bearing on young wood. The end leaves are shrivelling, the basal leaves have fallen and die-back is imminent.

is a long wait for the trees to mature and bear again on growth that may be weak and sappy, and the weakened rootstocks are given such a severe shock that many of them never recover.

Matters are improved when the trees are spaced farther apart, but troubles are bound to come if the climatic and soil conditions are not ideal. It is for these and other reasons that the multiple-stem system of pruning has recently been adopted for preference.

The multiple-stem system will be explained in later pages, when it will be understood why it may be the best method for most planters to use. Before this is admitted as a general rule we must see how Arabian coffee behaves in an environment where the conditions are entirely satisfactory for healthy growth.

To begin with growth is much slower, and the main stem is very sturdy. There is no comparison between a young Arabian coffee plant grown in a cool, moist climate, and another reared in a warm lowland region where the rainfall is unevenly spread. The one grows like a healthy child and the other is drawn and sickly. In place of a pale green colour the leaves are a dark green, and they persist, as they should on an evergreen, for a much longer period of time. The branches, too, are stronger, without that weakness which invites die-back, and the first good crop is not borne until the fourth year from planting.

The most astonishing difference is that the crop is more seasonal, and it is mostly borne on the older wood. The young green wood is usually devoid of flowers and immature fruit, so that the tree is in balance, and the leaves can devote themselves to the manufacture of food for the roots and the branches, and store enough extra food to provide for the seasonal flowers and fruit. Meanwhile they have sufficient to preserve their own freshness and strength. No authority appears to have recorded this fact before, though it can be clearly demonstrated on the slopes of Kilimanjaro at an altitude of 5,000 feet. From about 4,500 feet upwards on the south-eastern slopes the trees bear on the old wood, but at lower levels the trees tend to bear on both the old and the young wood, until, at the lowest level, the fruit is borne only on the young wood. At the higher altitudes the main trunks of the trees are three and four inches thick, and they are sometimes encrusted so thickly with berries that patches of the bark are hidden from view. The branches are also heavy with clustering fruit wherever the wood is mature.

When this is the case, the trees are able to bear successive crops without undue exhaustion, and one begins to wonder if a multiple-stem method of pruning is the best to use in such a region. To suggest that this is so without ample test is much too sweeping, and it is significant that the Lyamungu Coffee Research Station lies at an altitude of only 4,400 feet on Kilimanjaro in an environment which cannot be said to be as good for coffee as are the slopes further east at a higher altitude.

One of the drawbacks of the multiple-stem system of pruning is that the production of sufficient upright growths from the base of each plant is not always easy. The inherent character of the Arabian coffee tree is to produce one main trunk, and no matter if the plant is stumped, or the stem bent over, the tendency is for the most favoured bud to break and precede any other that might grow. It is thus not always easy to obtain and maintain three stems of equal size and strength. Sometimes it is difficult to obtain a second or a third stem at all, when an old tree is ruthlessly stumped back, unless the

tree is planted in one of those warmer and less satisfactory regions where growth is more prolific and fast.

The satisfactory attainment of a multiple-stem growth may well depend on fast growth and the correct climatic conditions, and be more difficult to obtain in a cold, moist region where coffee grows slowly. It is therefore arguable whether or not the older single-stem method might not be the best to practise in cooler regions, and the author would hesitate before he tried any change. The multiple-stem method aims at obtaining plenty of young bearing wood and sacrificing the old, whereas in an ideal environment a coffee tree produces much of its crop on the older wood, which then becomes the most valuable part of the tree.

If the single-stem method is found to be the best in a favoured region, there are ways and means of helping the framework of the tree to establish itself and give ample and successive annual crops to a ripe old age, without exhibiting exhaustion or decay. It is then necessary to retain and strengthen the primary branches so that there is no danger of their dying back. This is done by what is known as 'capping'.

Capping is stopping the growth at intervals by pinching out the apical bud of the main stem, and this is done two or three times while the tree is growing; on the first occasion at knee high, secondly at waist high, and thirdly, perhaps, when the tip of the stem has grown breast high. After the third capping the tree is permitted to grow to its ultimate height of about five feet. This capping directs the strength and surge of growth into the branches in a very obvious manner, until terminal growth begins again with full force. There is not the slightest doubt that the branches are thereby strengthened and thickened, so that they become greater storehouses of food along their whole length. They are thus better able to support leafage which in turn supplies more food, and also the ultimate flowers and fruit without exhaustion. This strengthening is accomplished in four stages—three times when the cappings are done, and lastly at the ultimate stopping when the tree has grown its permitted height. There may be a little loss of time while the framework of the tree is built up in this manner, but compensation is given by the extra strength and steadier cropping afterwards.

When capping is done there are one or two rules to follow. The tip and its internode must be cut close to the top pair of laterals, otherwise a peg will be left which will not readily heal over. Secondly, if the top laterals were allowed to grow normally their weight might split the main stem where it has been severed, and this is prevented by pinching back the two top laterals to their basal pair of leaves. By the time the secondaries have grown, the danger of splitting will have passed. New uprights soon appear from the buds on the main stem; these occur, curiously enough, not in the upper axils of the laterals but immediately below them. There are usually a pair of these new uprights, and one of them must be pinched away before it has grown more than a few inches. A glance at Figs. 21 and 22 should make all these operations clear.

After the capping has been done and the framework of the tree has been built up, any further pruning follows the ordinary principles of single-stem pruning. This is never so difficult when growth is slower, and sturdier, in a favourable climate and environment. Contrary to the opinions expressed by several writers,[8] Arabian coffee trees in most temperate regions are sturdier; they do not create a prolific growth which is tiresome to prune and is made

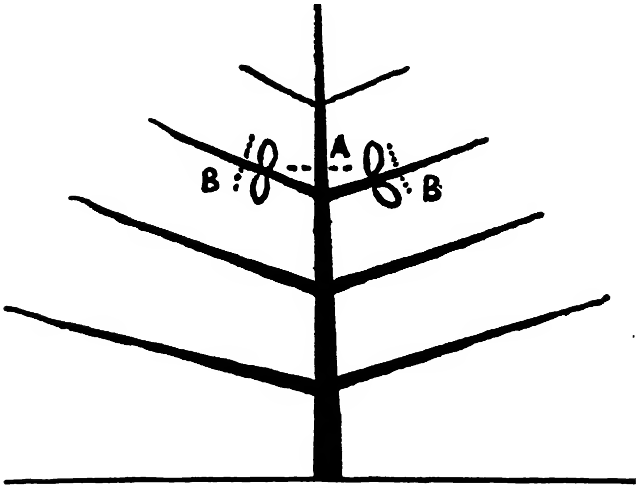


FIG. 21.—Capping a young tree. A—The leader shoot is decapitated knee-high; B—The top pair of laterals are pruned back to the basal pair of leaves.

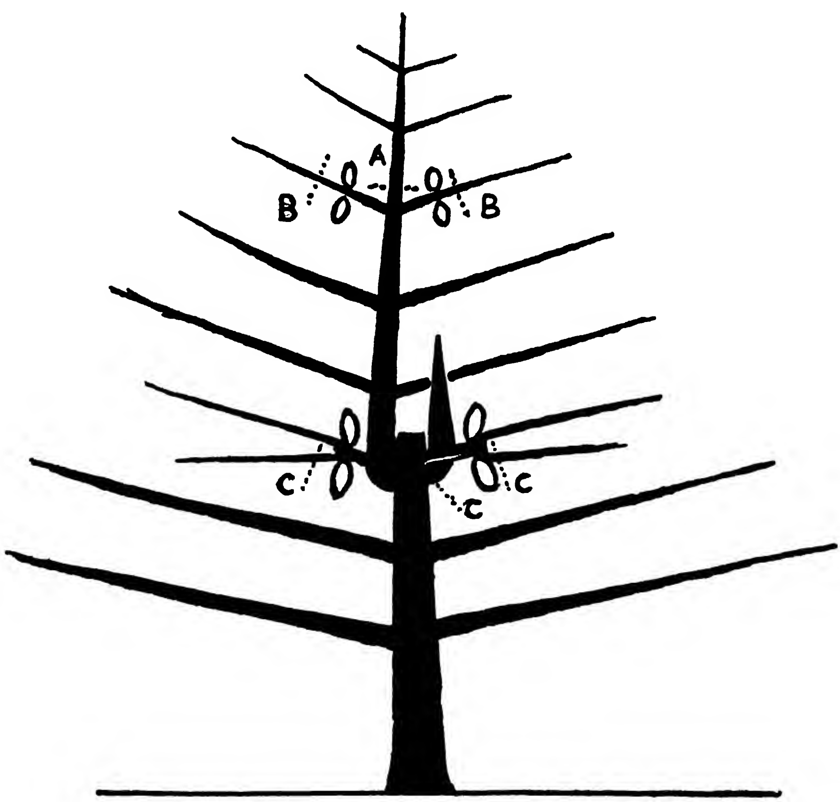


FIG. 22.—Capping. A—Second capping at waist high; B—Top pair of laterals cut back; C—Surplus growth pruned away at point of first capping.

at the expense of flowers. There is never such an abundance of spindly and prolific growth to prune away, and only a light annual pruning should be necessary after the seasonal crop has been harvested. Any sucker growth must be eliminated by regular de-suckering cycles, but even these are less frequent on account of the slower growth.

Capping is also effective when the trees are growing in country that is not quite ideal for coffee, but it only serves to postpone the evils of exhaustion. In

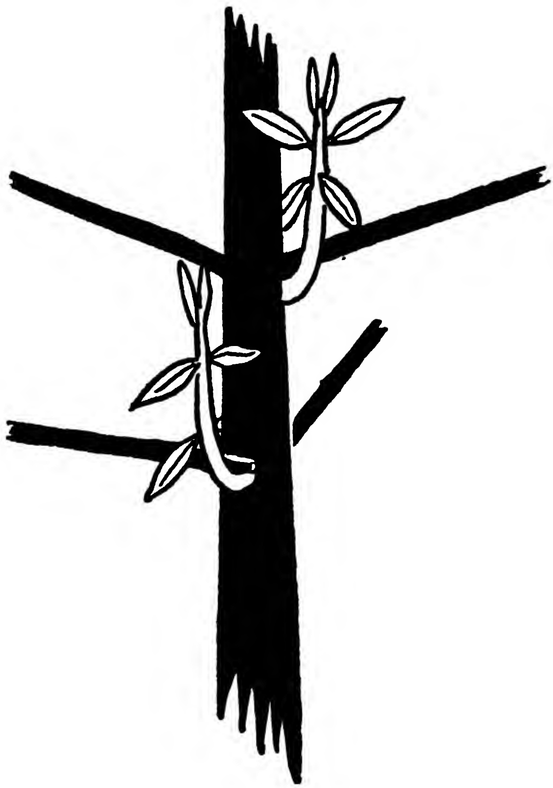


FIG. 23. Sucker growths spring from immediately below the laterals on upright or orthotropic stems.

such regions the case for multiple-stem pruning of one kind or another is strengthened, and though this is by no means a cure for exhaustion and sickness brought about by climatic or environmental deficiencies, yet it is a method of obtaining economic returns when conditions are not ideal.

SEVERITY OF ANNUAL PRUNING OF SINGLE-STEMMED TREES

In Southern India, the multiple-stem pruning of coffee started recently, and it is in this country that the closest attention has been given in the past to the effects of different methods of pruning single-stemmed trees. The results are interesting and not as one might expect. The figures given are the result of ten years' recording at Balehonnur.[15]

The trial was carried out with a local variety of *Coffea arabica* spaced 6 ft. × 6 ft. under natural shade, and the treatments were as follows:

A. *Light pruning*, which concerned de-suckering and the elimination of dead wood and crossing branches.
B. *Medium pruning*, which also included the cutting out of secondary growths in the centre of the tree and removal of whippy or blind wood.
C. *Heavy pruning*, which, in addition to A and B, included the thinning out of superfluous branches to alternate the bearing wood on the primaries and secondaries on the herring-bone system.
D. *Control plot*, where no pruning at all was carried out.

PRUNING EXPERIMENT.

AVERAGE YIELDS IN LB. CHERRY PER ACRE PER ANNUM.

	Ten years' test, 1940–1949	
A. ...	Light pruning	1,262
B. ...	Medium pruning	1,107
C. ...	Heavy pruning	1,037
D. ...	No pruning	1,037

Everything points to the fact that with Arabian coffee it is the training that matters and not the subsequent pruning of the tree. Light pruning, as one might expect, is beneficial, for it frees the trees from encumbrances, thus making it superior to medium and heavy pruning, although one might have expected the heavier pruning to encourage bearing on stronger and evenly spaced wood more amply supplied with nutrients.

Heavy pruning would seem to upset the balance of a tree, the natural growth of which is to sacrifice its lower primaries. If the tree is topped and the lower primaries are always heavily pruned, then they respond by extra leafage, and tertiaries, and so on, at the expense of flowers and fruit, just as a heavily-pruned tea bush is encouraged to flush new growth. Hence the rule should be to prune as little as possible, and since this would appear to be the case, the bogey regarding the complication of single-stem pruning tends to disappear. With an adult single-stem tree, the subsequent pruning might be easier to carry out than the multiple-stem or the agobiada systems, since rejuvenation would not be called for were it not for the fact that coffee tends to overbear its strength and suffer from die-back and exhaustion.

Exhaustion brought about by biennial or triennial cropping with its accompanying overbearing often ruins the framework of a single-stem tree. At the economic close spacing, because it is natural for the trees to discard their lower branches, they tend to assume the shape of umbrellas and the pruning becomes more complicated during these 'off' seasons when it is necessary to save the lower primaries from total extinction. Much must depend on the local environment, and in India the crop is refreshed by a heavier and more even rainfall than is found in many coffee-growing districts of East Africa.

It is therefore necessary to give a closer examination to these Indian results than the ultimate comparison of averages. It will then be appreciated that after a heavy pruning in the off-season of 1941, the heavily pruned plots gave a bigger return in the subsequent year than any of the other treatments. What, one wonders, would have happened if the trees had not been heavily pruned in that year? We do not know. Thenceforward, triennial cropping began on all four treatments, with the light and medium pruning giving almost equal returns until 1946, and then the medium and heavy prunings in 1947 brought these two treatments outstandingly higher yields in 1948, and again in 1949.

The figures are computed from 1940 to 1949 and the 1940 first-year figures favour the light pruning very greatly. However, even if the 1940 first-year record is eliminated, the figures still follow the same trend and show that heavy pruning over a long period of years is both unnecessary and depressing.

The results of a pruning trial at Kitale in Kenya are also interesting. The test started in 1940 on Arabian coffee that had been planted in 1938, and the treatments were as follows:

A. Single stem. Primaries reduced to 15.
B. Ditto. Primaries reduced to 20.
C. Ditto. Primaries reduced to 25.
D. Ditto. No reduction of primaries.
E. Multiple stem.

There was no impression of a regular response to any one pruning treatment in the separate seasons, but for a seven-year period ending in 1948 the inferiority of A and E treatments became evident. The single-stem trees yielded over 20 per cent more crop than the multiple-stem when the primaries were not reduced.

PRUNING TRIAL, KITALE.

CHERRY YIELDS IN CWT. PER ACRE.

	Treatments				
	A.	*B.*	*C.*	*D.*	*E.*
Total yield 7 years	176·7	217·2	223·7	232·6	181·8

The trees were twenty years old, and elsewhere in this book it is pointed out that single-stemmed trees become much more valuable as they grow older, the yield steadily increasing all the while. It is quite possible, therefore, that single-stemmed trees may be found to outyield trees trained to the multiple-stem method soon after their tenth year, especially when only light prunings are carried out.

In India, exhaustion and die-back are accompanied by leaf-rust disease, so the results of a further experiment are interesting. The figures given are the results of ten years' recording, and the treatments were as follows:

A. Spraying before and after the Monsoon rains.
B. Pruning only.
C. Spraying and pruning.
D. Control. No pruning or spraying.

PRUNING OR SPRAYING EXPERIMENT. AVERAGE YIELDS IN CHERRY AND CLEAN COFFEE IN LB. PER ACRE PER ANNUM.

TEN-YEAR TEST, 1940–49.

	Cherry	*Clean Coffee*
A. Spraying	1,609	289
B. Pruning	779	148
C. Spraying and Pruning	1,376	268
D. No spraying or pruning	801	143

It would seem that spraying alone to preserve the leafage has had the greatest effect, and that there is no significant difference in the yields between pruning and no pruning at all. One must therefore conclude that with the Indian environment and possibly in most other countries, only the lightest of pruning is required for Arabian single-stemmed coffee trees when once they have reached an adult age.

MULTIPLE-STEM SYSTEMS OF PRUNING

It is sometimes thought that the practice of multiple-stem pruning has always been common in Brazil. This is not true, for the method there in the past, and still often used today, is to sow seed at stake. Six or seven seeds are sown at each spacing in the field and the seedlings that survive the hazards of field cultivation are thinned to two or three. Hence several young trees on separate roots grow up together, and are treated as multiple stems, a practice which is by no means advisable in the light of modern knowledge. Each tree struggles with the other for its share of nutrients, moisture, and light, and if one stem must be cut back to encourage new growth it is the whole of the tree that suffers the loss of its top growth with a considerable shock to its roots. The trees that are left are given an advantage in the struggle with their neighbour, so that a spindly growth results from the one that has been cut down.

The author was on a visit to Kenya when coffee planters began to stump back old single-stem trees with the purpose of a change-over to multiple-stem pruning. Whole plantations were cut down, leaving stumps no more than a foot high, and a great number of the rootstocks died from shock. Those that lived threw up feeble suckers, and if these gained in strength there was often one which took the lead to the detriment of the others. Great difficulty was experienced in achieving the number of stems required from the stumps which survived, and no account had been taken of the best time of the year for the stumping to be carried out.

STUMPING BACK OLD TREES

Should anyone desire to cut down old single-stemmed trees to gain a multiple-stem growth instead, there are common-sense horticultural precautions to take to lessen the shock and gain the end in view. A multiple-stem system obtained in this manner, however, rather late in the lifetime of a tree, will never be as good as one which has been developed in the beginning.

Firstly the trees should have all their 'primaries' completely cut away except for a few at the top, and no crop should be allowed on the branches that remain. These top branches will help to feed the roots until suckers have grown from the main stems, encouraged by the minor shock given to the trees by the loss of most of their primaries. To encourage the suckers to grow from the basal part of the stem, nicks may be cut in the bark of the trunk immediately above the pegs where the lower primaries have been cut away.

The reason for this must be understood. A plant passes the moisture and dissolved nutrients it has obtained from the soil through the tissues near the central column of wood to the leaves of the branches. The leaves receive these nutrients, and together with the power of sunlight, and the air they breathe, are able to manufacture starch and sugar. The right kind of food is thus produced which may be moved about to wherever growth is taking place, and as this food is transported in the tissues of the bark, there is a return flow in a downwards direction, particularly to the growing roots. Should the bark be nicked, then the downward flow of food at that place is interrupted until the wound heals. A dormant bud below the nick is thus encouraged to sprout and make up for the interrupted flow of food. This is, of course, a simple and rough explanation of a very complex happening. Hormones are involved, and all the wonderful aids which Nature has at her command to save life and overcome the disasters which human agency may bring to the tree.

By making these nicks in the bark above the places where growth is desired, the emergence of suckers is more likely than if the matter had been left to chance. Although many practise ring barking, one should never cut a ring of bark away from the whole circumference of the tree, because this is as bad as cutting down the tree. Unwanted suckers which appear higher on the trunk should be pinched away before they have grown an inch.

In course of time a healthy bunch of suckers may be obtained round the basal part of the tree, and when these have begun to form 'primaries' the old branches at the top may be sacrificed and the tree be stumped back as far as the new sucker growths. Stumping should not take place, however, until the rains have started after a dry spell or just before the annual flush of new growth begins. At the same time, any surplus suckers should be removed leaving only three of the best growing from different sides of the stump. A sharp pruning saw must be used to cut through the trunk close to the base of the top sucker, and all the roughness of the cut must be pared away with a sharp knife afterwards to assist the healing of the wound. A slanting cut is advised when stumping back a thick trunk, *see* Fig. 24.

In this manner an old plantation of single-stemmed trees may be changed over to multiple stems in the safest way. The soil must be kept cool and moist by using mulches, and everything possible be done to aid the roots of the old stumps to carry new and sturdy growths. One of the disadvantages of obtaining multiple stems by stumping back old, or even young trees, is that the suckers sprout rather close together. As they grow bigger their loads of fruit make them bend away from each other, and there is then a tendency for them to split away from the stump. Another disadvantage is that borer beetles can be more troublesome among close-growing multiple-stemmed growths in regions where they are common pests.

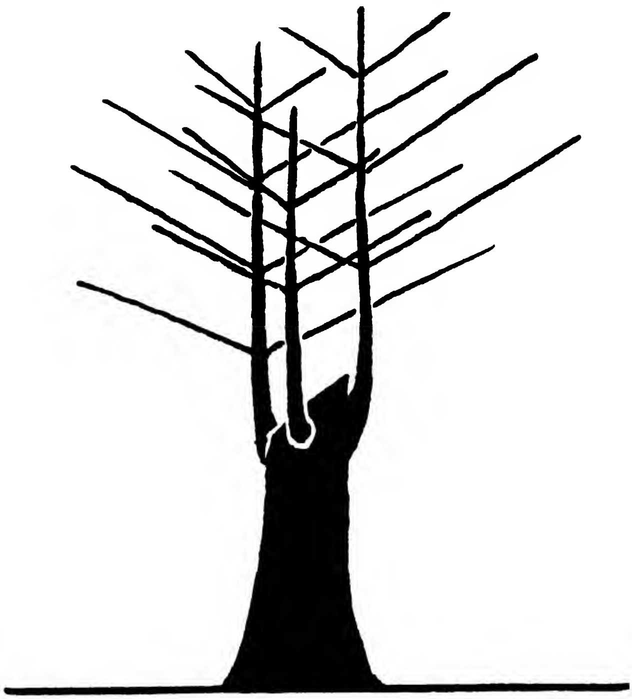


FIG. 24.—Stumping completed.
Note slanting cut close to where the basal growths spring.

MULTIPLE-STEM SYSTEMS: TRAINING OF YOUNG ARABIAN COFFEE TREES

Two methods which have been in use are not sound according to the strict rules of horticulture since they savour more of wholesale farming methods which are not applicable to orchards. They are hasty, slip-shod methods, adopted for ease and economy of time and labour, and may affect the ultimate health and stamina of the plantation.

The first is to grow eighteen-months-old seedlings in the nursery until they have grown lateral growths and stems about the thickness of a little finger. When planting time comes along these are dug up by the score and the top growths cut away leaving stumps six or eight inches long. The roots are also pruned short and the stumps are planted in the field in the filled holes. It is sometimes argued that there is no wilting and transpiration of moisture from the stumps, that they begin to sprout new shoots and new roots without much delay and without the necessity for early shading in the field. In fact the mortality rate is very high, often approaching 30 and 40 per cent.

The second method is to grow similar leggy plants crowded together in a nursery until they are nearly waist high. These are dug up and planted as soon as possible in the field, after awkward and damaged roots have been pruned away with a sharp knife. They are watered in and given temporary shade in the field, and though wilting generally takes place the trees are said to recover and soon catch hold if they have been planted at the right time, i.e., when the rains have obviously begun.

Photo by author

(*a*) Young robusta, *Coffea canephora*, bent over to develop the Agobiada system of growth, Bukoba District, Tanganyika

(*b*) *Coffea liberica* in Malaya. Growing on a 'muck' soil in the State of Selangor.

By courtesy of the Department of Agriculture, Federation of Malaya

PLATE XXXIII

When the young leggy trees in the field have recovered from the shock of transplanting, the tips of the stems are bent over and pulled down until they touch the soil, and they are fixed in this position either by being pegged down by a stout hooked stake, or are tied to a peg firmly fixed in the ground. The stems of the plants near ground level should by now be as thick as one's third finger, and they are bent in the shape of an arch from which new upright growths will appear. For the sake of tidiness and ease of working they are all bent in the same direction north or south, east or west within the rows.

It does not take long for new uprights to sprout from most of the eyes along the arched portion of the stem, and three of the best that grow from where the arch begins, and spaced an internode or two apart, are selected to form the multiple-stemmed tree. The growth of these new uprights is rapid, and by the time they, in turn, have made laterals, the arched stem of the original seedling has thickened and become set. It will not then spring back into an upright position when the tip is released from its tie. The original stem will also have grown longer, and may have begun to curl upwards at the tip. Some of its laterals may have begun to bear a 'fly' crop of fruit, and under the true agobiada system the tip would be released and it would be allowed to remain as part of the tree. It is best, however, to cut back the old stem at this stage to where one of the new uprights has grown.

A better and sounder method of training a tree on the agobiada system is to plant seedlings with only six pairs of leaves; this, in the author's opinion, is the best size to plant out from the nursery. These are grown in the field to nearly waist high before they are bent over.

Firstly the young trees will not be leggy and bare of leaves, and when the time comes to bend them over, the lower laterals must be pruned away, so that the sturdier portion of the bent arch is now bare of growth. This will help to urge the new uprights to sprout. Secondly it may be found that the upright stems are so sturdy that they cannot be bent over to touch the ground in one operation without fear of breakage. Some might argue that this is a disadvantage, if a sturdier and healthier growth can be considered as such. Others will realize that a stronger growth above ground signifies that there is a better root system as well. No one should grudge the extra care which is needed while bending the tree to form an arch, and to achieve this it might be necessary to do the job in two operations: firstly half-way, and secondly a fortnight later when they may be bent with safety to the required amount.

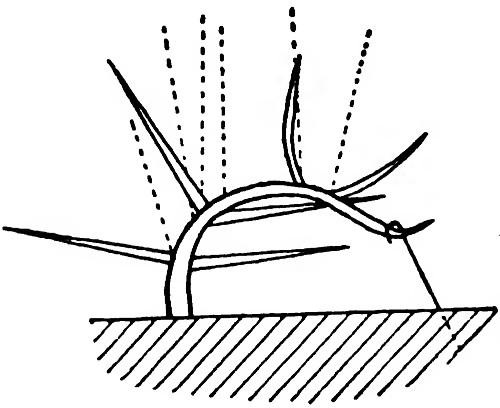
EAST AFRICAN MULTIPLE-STEM PRUNING

The difference between the agobiada system and the East African multiple-stem system is, that the seedling is not bent over but topped when it has reached a little more than a foot high. This first topping, which is often done in the nursery before the plants are planted out in the field, produces two vertical growths which are soon topped again to produce four, if more than two upright growths are desired.

No matter what system of planting and training has been adopted, the usual practice is to obtain three or four sturdy upright growths to replace one single stem, and to have them growing up together about the same size and of equal strength. Although the young sprouts have been chosen as far apart as possible, the ultimate growths will be crowded for a while, even when they begin to flower and fruit. The branches will be interlaced in the centre of the

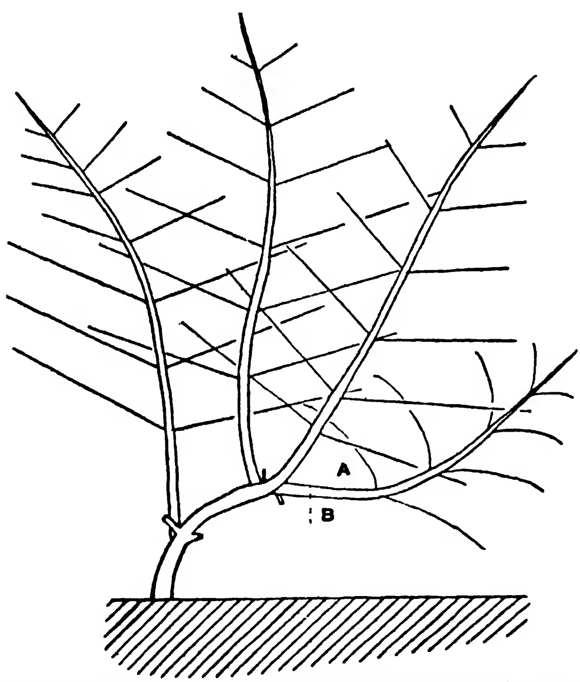
bush in a way that is an eyesore to a trained horticulturalist, to one who believes that branches should not interlace, and that there should be plenty of light and air in the centre of a fruiting tree.

Be this as it may, the matter may be disregarded, because it will only happen for a short while. These three main growths soon grow tall, and the weight of fruit on their upper branches and the pulling of the pickers to reach the fruit, soon force the stems to bend away from each other. Thus the centre of the tree is opened to the air, and the interlacing branches are pulled apart.



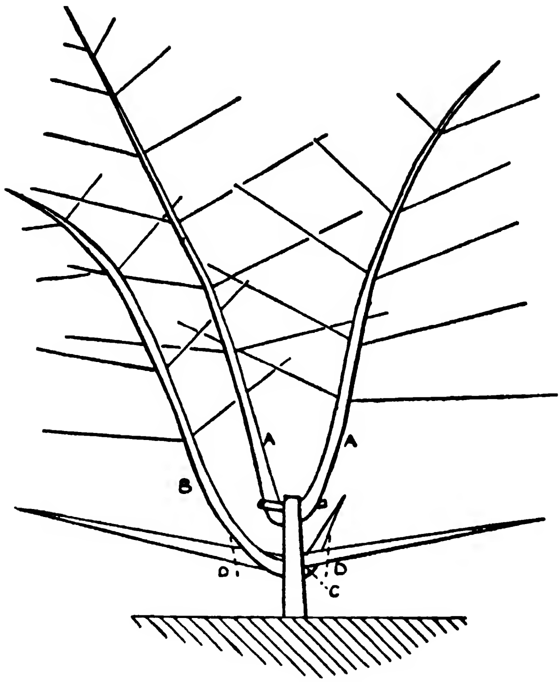
By courtesy of the Department of Agriculture, Tanganyika Territory

FIG. 25a.—Agobiada Multiple-Stem Pruning. The young plant has had the main stem bent over and tied or pegged down. The dotted lines show whence leader shoots may be expected to grow.



By courtesy of the Department of Agriculture, Tanganyika Territory

FIG. 25b.—Agobiada Multiple-Stem Pruning. The plant advanced in age. Three of the strongest shoots have formed new leaders that are beginning to bend away from one another. Pruning is similar to the 'Long Top' method. The original leader shoot A can either be allowed to remain, or be pruned away at B.



By courtesy of the Department of Agriculture, Tanganyika Territory

FIG. 26.—Multiple-Stem or 'Long Top' Pruning. A—Two leader shoots, and B—a third leader encouraged by pruning away the lower primaries at D; or by recapping the new leaders A. The multiple stems are beginning to lean away from one another and the lower primaries, becoming exhausted, have already been pruned away. No secondaries are allowed to grow. If a fourth leader has attempted to grow, it has been cut away at C. There should be no difficulty in obtaining new shoots eventually, to take the place of one or more of the original stems when they show signs of weakening.

As the stems go on growing taller the lower laterals fruit, become exhausted and are of no further use. They are then pruned away close to the main stem with a sharp knife, and in course of time the uprights are bare of growth for several feet from where they fork at the base of the tree. Pruning is, therefore, quite simple, and well within the intelligence of unskilled men when once they have been shown what to do. Only unproductive and dead wood is cut away.

Some Kenya planters carry out the system known there as 'cutting up', instead of selecting the branches for removal as they become exhausted. It is thought that four to five feet of bearing upright stem are sufficient for each head of growth, and the pruner is given a stick cut to the requisite length which he pushes up until the top of the stick is level with the end shoot of the head. All primary branches which exist below the bottom end of the stick are then removed. The same stick is then placed with its bottom end on the ground, and if the coffee stems are bare of growth for longer than the stick, then one or two suckers for each stem are selected at the base to remain. Until this stage all suckers are removed, and no sucker is permitted to sprout nearer to the ground than about nine inches to one foot.

Saw-men follow the pruners, and if a pruner decides to remove one of the

main stems, he breaks the top growth to indicate to the saw-men that this stem must be sawn away at the base. The saw-men are trained to cut back the growths in the proper manner close to the basal suckers. When there is much saw-pruning to be done, it is best to finish off a cut with a mallet and chisel, rather than try and make the saw cuts too close to young growths.

In such a manner each tree is left with about the same quantity of bearing branches and thus the crop yield is controlled. A reduction in crop during bumper years can be obtained by cutting up higher. This arbitrary method of pruning multiple-stemmed trees is not advised by the author, though it may be economic and necessary where labour is unintelligent.

Earlier cropping has been observed on plantations that have adopted multiple-stem pruning. In parts of Kenya the season of main crop has been changed from between August and December to May and July.

After the stems have begun to bend away from each other with the weight of fruit, harvesting may be done with the aid of a short step-ladder, or by pulling the branches within reach. There comes a time, however, when, by the use of foresight it will be perceived that the old stems will soon have grown too tall or spindly and beyond their usefulness. Meanwhile it may be seen that young sucker growths have begun to sprout from the base of the tree. Those that sprout too high on the three stems should be pinched away as they form, but of those growing at the base, one or two of the best may be selected to grow in succession to replace the old main stems. As these mature and grow upright in the centre of the bush, they in turn will begin to form laterals, and it is at this time, when one or more of the older stems may best be sacrificed and cut back to near the base, so that the younger growths may take their place. They should be cut carefully with a sharp pruning saw, and the wound pared with a sharp knife or chisel.

The aim is at cutting back the older stems in succession, perhaps one each year, so that the younger growths also replace them in succession; the whole pruning system is thus easy to understand. If sucker growth does not sprout of its own accord, then one of the main stems can be cut back a little earlier so that sprouts are obtained from its stump.

In theory, the multiple-stem system of pruning is beneficial because the tree and its roots are constantly given vigour by the growth of the uprights. There are always fresh young growths and leafage at their tops pulling up the sap and returning food to the roots, and all the exhausted branches are pruned away so that they do not rob the tree of strength. This should lead to regular yields, and if all this be true, then the multiple-stem method is indeed the best system to use in all those regions where there is something lacking in the environment which forces the tree to bear on its young wood.

Since there is a healthier bearing surface and young terminal growths, a multiple-stemmed tree should give a heavier crop than a single-stem tree if the yield is not balanced by the need for a wider spacing, especially in the early years.

An experiment was started at Lyamungu, soon after the station was opened, to discover which system of pruning would give the best yields. The results appeared to be in favour of multiple-stem pruning in the beginning, in that particular environment, and though it is difficult to find mention of the planting distances in the successive annual reports, one presumes that the same were given to both, and that the spacing throughout was nine feet by nine feet. The following table shows that for the twelve years from 1939 to

1950, the average yield of the multiple-stemmed coffee was at the rate of 11·03 cwt. per acre, or considerably more than that of the single-stemmed coffee at 7·9 cwt. per acre.[12] It would be interesting to start a new experiment, where the multiple-stemmed coffee was given wider spacings, for an extra foot space might well be rewarding in some regions.

MULTIPLE-STEM ARABIAN COFFEE VERSUS SINGLE-STEM AT LYAMUNGU.

Treatment	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*1948*	*1949*	*1950*	*Aver-age*
Single-stem	1·982	2·996	7·290	3·991	5·318	5·319	9·589	1·04	20·492	9·318	15·052	12·362	cwt. 7·895
Multiple-stem	2·348	11·928	12·962	12·034	17·238	5·677	7·079	2·30	29·578	5·056	12·701	13·446	11·029

A matter of great interest in studying the tabulated results is the way in which the yields have increased throughout the years, more especially those of the single-stem coffee, which for the last three years have beaten those of the multiple-stem coffee by as much as 1·84 cwt. per acre. One wonders what the results might be in another twelve years, and it shows how dangerous it is to draw conclusions too hastily. It rather adds weight to the suggestion repeated in this book, that a multiple-stem system of pruning might not be the best where the environmental conditions are ideal, and especially where coffee bears its crop mainly on the old wood.

A pruning experiment was carried out over a period of years at Kampala in Uganda, with the var. *arabica* 'Nyasa' strain of coffee planted under the shade of the rain tree *Pithecellobium saman*.[16] The yields over a period of nine years were:

Treatment	*Fresh cherry lb.*
Single-stem	530
Multiple-stem ...	678
Agobiada	826

The spacing was 10 ft. apart, which is generally considered too wide for multiple-stem Arabian trees, and is certainly too wide for single-stemmed coffee. Despite the findings that yields are increased by closer spacings, as will be shown, the author favours a 10 ft. × 10 ft. spacing for multiple-stem trees, and a 9 ft. × 9 ft. spacing for single-stem pruning, because the health and strength of each tree will be preserved, and the lifetime of the orchard be prolonged. Had this spacing been given in the experiment, it is possible that the latter would have shown a higher yield. It will be seen that the agobiada system, unlike the Tanganyika trial, has out-yielded the multiple-stemmed plots.

Irrespective of such remarks, the multiple-stem methods of pruning are easier and far more economical to carry out, especially when pruners are not highly trained. Wherever Arabian coffee bears on its young wood, as it generally does in Uganda, it would be wise to disregard the difference in yields, even though they might favour single-stem pruning under different spacing, and adopt the multiple-stem system throughout.

Trials by Jones[6] in Kenya over a period of seven years gave the following results.

YIELDS IN CWT. CHERRY PER ACRE.

Plots	*Single-stem*	*Multiple-stem*
At Kitale	232·61	181·75
Mount Elgon unshaded ...	276·83	201·78

These results bear out the opinions of the author who would prefer single-stem pruning in an environment suited to Arabian coffee. The fact that the coffee on Mount Elgon was unshaded indicates that the planting was at high altitude, where bearing on the older wood is common in East Africa. Kitale is at an altitude of over 6,000 feet and the temperatures are cool.

Kerr's experiments[7] concerning pruning trials at Bugusege in Uganda show that the yields of the agobiada system transcend those of single- or multiple-stem pruning. This is in contradiction to the findings at Lyamungu.

YIELDS IN CWT. RIPE CHERRY PER ACRE.

Totals for 11 years ending 1940.	
Single-stem	282
Multiple-stem	439
Agobiada	567

Comparing the yearly notes which accompany the annual reports of this trial, it seems that in the aggregate there was little difference in the long run regarding the out-turn and quality of bean. The last report states that 'Agobiada is obviously the best, and this treatment suffered very slightly from die-back when the other two treatments suffered severely. Trees of multiple-stem recover to some extent, but the single-stem trees die out and this method of pruning must be condemned for low elevations in Bugishu.' Fluctuations in yield proved less marked with agobiada than with the other two systems.

Reporting in 1947 on an experiment laid down in 1932 to test a natural or unlimited growth against a modified multiple-stem system of pruning at various spacings, Maidment, in Uganda,[10] gave the following results.

TOTAL YIELDS IN CWT. FRESH CHERRY PER ACRE.

	Spacings			
	8′ × 8′	7′ × 7′	6′ × 6′	4′ × 4′
Unlimited natural growth	499	479	550	687
Modified multiple-stem	463	541	523	518

It seems that yields were vastly superior at the closer spacings when the trees were young, for the reason that the number of trees was so much greater.

Despite the fact that the 4 ft. × 4 ft. spacing showed a distinct inferiority to the wider spacing in the 1944–45 season, the heavy yields in the earlier years were still reflected in the totals. As the trial continued, the modified multiple-stem plants began to give better yields than the natural growth trees; also the wider spacings were giving the best yields.

The lessons from this test are many, but they might vary if the same trial was carried out in different environments. A planter naturally wants good yields at first to recover maintenance costs while his plantation is in early growth. Close-planted single-stem trees would appear to offer high yields in the beginning. Close planting at low altitudes and in short-rainfall areas, would, however, cause too much root competition for moisture supplies, as the trees became adult, and it has been proved that a well-planted and well-managed estate of old coffee, is far superior to a young one. It would obviously be silly to ruin the potentials of the future by exhibiting greed early on.

Even so, these results would appear to show that a very sound procedure might be to plant at 5 ft. × 5 ft., training the plants alternately to the single-stem and agobiada systems, with the object of cutting out the single-stemmed trees completely after the third year's cropping, at lower altitudes. The multiple-stemmed trees would then be 10 ft. × 10 ft. apart, and the future health of the plantation be assured. It might be a little risky in regard to the future, say in twenty or thirty years' time, if the plants were set at 4 ft. × 4 ft., and then reduced to an 8 ft. × 8 ft. spacing on a multiple-stem system.

UGANDA SYSTEM OF MULTIPLE-STEM PRUNING

For the African-grown Arabian coffee, the policy of the Uganda Agricultural Department has been to top the young plants in the nurseries above the first few pairs of leaves, a few weeks before the plants are issued for planting. The buds of new uprights begin to swell and sprout earlier in the field. Only two uprights are allowed to grow and produce fruit on their primaries before others are permitted to grow in succession. It is not known why only two uprights are employed, and not three, unless it helps to simplify the subsequent pruning operations for the native planters.

MULTIPLE-STEM IN MEXICO

It is amazing to see some of the old Arabian trees in peasant gardens of Mexico. Bourbon coffee is the chief variety used and the trees appear to grow in a much more virile way than they do in either Africa or India. The stems grow fast and do not thicken out to the same extent, and beyond encouraging multiple stems by either topping or bending over the main stem, no pruning at all is attempted by many of the growers.

All the basal vertical sprouts are allowed to grow, and as these stems grow tall they bend away from each other and are kept in being until they arch over and touch the ground on all sides. Long before they do this, more uprights grow in profusion from the arching portions of the original uprights, and these grow thickly and somewhat spindly but bear enormous crops. The spread of one tree is immense, and the trees are spaced haphazard in many a coffee garden. One might call it a natural multiple-stem growth attained by discouraging a single stem at the beginning, and only when the older stems

become utterly unproductive are they hacked off at the base, where new sprouts spring from their stumps. Trees may be seen which are more than fifty years old and yet bearing enormous crops.

It is fair to state that in recent years the authorities have been doing their best to teach better methods of training and pruning the trees.[2] The peasant people are conservative, and hence a policy must be persuasive and supplementary rather than too drastic. The true agobiada system is now preferred for young plantings, and rejuvenation is advised for the old trees.

Rejuvenation consists of reducing the original stems, cutting away dead growth and old primaries, and reducing the number of secondary verticals that grow from the arching stems.

The old coffee gardens are literally a jungle of fruiting growth to which little is done except gather in an abundant harvest. An orthodox coffee planter must look at the trees with a wry smile, and wonder if his own modern methods and special care are worthwhile. One must remember, however, the environmental differences and the very important fact that there is no leaf rust disease as yet in Central America.

CANDELABRA PRUNING SYSTEM

In Guatemala and Costa Rica a multiple-stem system is built up on a system of capping the vertical shoots.[9] *Coffea arabica* var. *arabica*, *Coffea arabica* var. *bourbon* and *Coffea arabica* cv. 'Maragogipe' are grown. The spacing in Guatemala is usually triangular and 12 ft. × 12 ft., whereas in Costa Rica square planting is practised at 11 ft. × 11 ft. apart.

The apical shoot is topped when the young plant is from twelve to fifteen inches tall about three to four months after planting in the field, though some do this immediately if the plants have made two or more pairs of primaries. This encourages the growth of two vertical growths on opposite sides of the top node, and these are again topped when they are about two feet tall. When the trees begin to bear a fair crop, the weight bends the branches outwards and this facilitates picking. In course of time more upright sucker growths spring from the lower trunks of the tree, and of these several may be selected to replace any of the main branching uprights which become exhausted. These new growths are similarly stopped on the candelabra system to multiply the stems and rejuvenate the bearing section of the tree.

Some authorities[5] are meticulous in explaining the candelabra system, and of how growth is built up in tiers up to the third and fourth generation, but they find it difficult to find an explanation, other than that in the foregoing paragraph, of how the system is maintained. It seems obvious that the candelabra system has no future, and that in course of time it must break down into a rather ragged and awkward multiple-stem growth.

ROBUSTA COFFEE

PRUNING SYSTEMS FOR ROBUSTA COFFEE

The best pruning system to adopt for robusta coffee depends entirely on the variety or form grown. In the chapters on the botany of coffee it will be seen that there are two forms of growth, i.e., the upright tree-like form similar to the 'No. 9' selection in Uganda, and the kind which ultimately grows into

Photo by author

(*a*) *Coffea arabica* var. *bourbon* Grown in a highland temperate region Note the strength of the lower primaries after capping, Tanganyika

(*b*) *Coffea arabica* var *bourbon* A young tree recently capped at Nyakato, Bukoba, Tanganyika Note slender growth since the region is too warm for Arabian coffee

Photo by author

PLATE XXXIV

By courtesy of the Kenya Information Office

The practice of growing trees too closely and too long in the nursery produces a leggy growth

PLATE XXXV

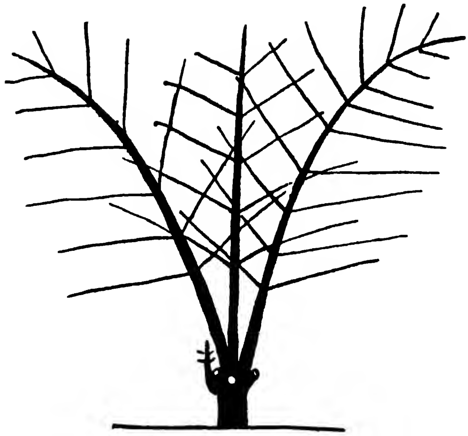


FIG. 27.—Diagrammatic arrangement of branching multiple-stem system of pruning *Coffea canephora* No. 9 selection.

(*Sketch by author.*)

a great dome-shaped shrub, such as the *nganda* variety. Before discussing the pruning of these two varieties it is as well to remember one difference which exists between Arabian and robusta coffee. When the laterals of Arabian coffee die they are held on the tree for a considerable time and require pruning away, whereas robusta coffee does not hold its dead wood in position for very long. It becomes brittle and drops away.

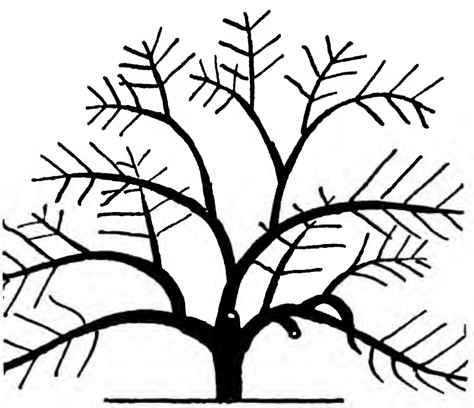


FIG. 28.—Diagrammatic arrangement of branching habit of *Coffea canephora*, var. *nganda*.

(*Sketch by author.*)

With both forms of robusta coffee the single-stem method of pruning is of no avail, since the lower branches are sacrificed by the tree and an umbrella-shaped growth is left no matter how hard one tries to strengthen the lower 'primaries'. The best plan, therefore, is to let both trees have their way as far as it is possible. Let the upright form grow tree-like, but on a multiple-stem system; let the shrubby type grow into a tremendous bush, and assist it by using an exaggerated agobiada system of pruning. (*See* Fig. 27 and 28.)

THE TREE-LIKE FORM

Any variety having a strong upright type of growth should be trained in the beginning to adopt a multiple-stem system of growth, either by topping or by the agobiada system, whereby two or three vertical stems are produced which may ultimately tend to bend away from each other, though the growths of the upright forms are so much stiffer than Arabian coffee that they may remain

erect beyond their term of usefulness. The verticals are renewed by cutting them back near the rootstock, and in succession as the years go by, so that new sprouts will shoot from the stumps.

It must be remembered that robusta coffee flowers and bears very early, often in the second year after planting. Also the stems of young plants are so stiff and strong that when they have reached a sufficient height to bend over, not only may the lower primaries be flowering but the stems are often very difficult to bend without breaking. For these reasons it is better to top the trees above several pairs of primaries to obtain multiple uprights. Meanwhile the lower primaries will give some fruit.

TRAINING THE SHRUBBY FORM

One might say that the natives of Uganda, and of Bukoba district in Tanganyika Territory, have shown the way to train the shrubby form of robusta coffee, which in Uganda is called 'Nganda' coffee, and in Java is known as Quillou coffee. In short, the waist-high seedling plant is bent over until the tip arches downwards and is then tied to a peg. The shoots which sprout from the arched stem are in turn bent over in various directions and fixed in the same manner until they have thickened and become set, after which they are released to grow naturally. Yet a third crop of suckers grow from the second series of bent stems when the subsequent weight of fruit bends them down, and these are permitted to form the centre of the tree.[4]

Thomas states[14] that genetic factors are partly responsible for the good yields from spreading forms, but that both the forms and their yields are improved by the method of training copied from that practised long before Europeans arrived in Uganda. He describes the practice as follows:

> 'When the seedlings were one year old they were bent over and tied down to a stick as in the agobiada method. Suckers from near the base were bent sideways and tied down a year later, providing four to six radiating stems growing outwards. Erect shoots from the upper sides were allowed to grow. The trees were eventually in the form of a fountain with a constant succession of young branches (uprights) from the centre. No pruning was done. Young branches were retained and as the crop was harvested, they were pulled outwards. Some trees may reach a spread of twenty-five feet when no more than six feet in height.'

In course of time the shaded portions of the stems drop their leaves and lower primaries, and a branching system develops within the shrub somewhat like a rhododendron bush. As the successive stems bend over with the weight of fruit, so do more uprights grow until the shrub is dome-shaped and comprised of multiple stems tipped with bearing laterals and young growth. A single old tree in the Bukoba district of Tanganyika may cover a circular space more than thirty feet in diameter, which gives some idea of the spacing required, and of how impossible it becomes to pick the ripe fruit except from the branches within reach. The berries beyond are permitted to mature, and are then shaken down on to tarpaulins or matting from which they are gathered up, then dried and hulled.

Other than giving assistance to the tree in assuming its dome-like structure by deliberately bending a branch here and there, subsequent pruning would entail the cutting away of dead branches and diseased growth. The pruning

method is economical and easy to understand, provided the trees are being grown in their correct environment. If the temperatures are too cold, or too hot and dry without the necessary humidity, then the trees do not thrive, for growth is slow, unhealthy, and uneven, resulting in ragged specimens that look more like scarecrows than well-grown coffee bushes.

Thomas[18] laid down an experiment in Uganda in 1930 to test the yields of robusta coffee pruned by various methods. Yields were recorded until the 1937 season and are given as follows:

AVERAGE YIELDS IN OZ. FRESH CHERRY PER TREE

Method of Pruning	*1932–36*	*1937*	*Total*
Single-stem	729	143	872
Agobiada	973	175	1,048
Multiple-stem—Costa Rica	889	175	1,064
Multiple-stem—Costa Rica modified ...	816	161	977
Multiplo-stem ordinary	842	178	1,043

It is remarked that the spacing of 8 ft. × 8 ft. was too close to allow the proper development of the trees, so that yields grew less on this account in the later years. Despite this fact, the average production per tree in less than eight years after planting amounted to 1,004 oz. of fresh cherry. Since the average ratio of dry robusta beans to fresh cherry is 22 per cent, the yield corresponds to 13¾ lb. of dry beans per tree or over four tons per acre. Until overcrowding began to upset the yields, the agobiada system of pruning proved to be superior to all others.

LIBERIAN COFFEE

TRAINING AND PRUNING

Most forms of Liberian coffee also tend to make large shrubs, rather than trees, when they are grown in plantations under cultivation. In fact it is wise to try and make them so by helping multiple-stem growth to develop, thus curbing their tendency to grow too tall. Some forms begin to flower and fruit in about the time it takes for Arabian coffee to bear, if they are grown on a single stem, so any form of control to encourage multiple stems would take another season's growth.

Since the Liberian coffee bush is much larger than either robusta or Arabian coffee if it grows as it should in its proper environment, a wider spacing is required to correspond. It is surprising to find the single-stem method of pruning advised in Malaya, where the trees are topped apparently at 5 ft. 6 in. and planted 10 ft. × 10 ft. apart.[1]

EXCELSA COFFEE

TRAINING AND PRUNING

Except for small holdings and plants in botanical gardens and institutions, excelsa coffee exists only in the wild state, where it grows naturally into a tall

tree with a clean trunk of considerable size. Should an attempt ever be made to grow excelsa coffee on a plantation scale it would need at least a forty-foot spacing. Any pruning it might require would be done with the object of assisting it to grow into a mature tree as quickly as possible.

Sucker growths would have to be eliminated as soon as they appeared, to direct all the strength into the main stem. The lower branches would also require to be pruned away flush with the trunk as soon as they showed signs of exhaustion. In course of time a high canopy would be formed from which the dried mature fruit would fall for collection from the ground. The sooner such a canopy was formed to shade the soil, reduce weed growth, and bring maintenance work to a minimum, the earlier an economical production of this low-priced coffee might be achieved. The species would, of course, never be grown on land and in an environment suited to the better and higher-priced coffees.

Wherever excelsa coffee is grown and said to be shrubby in nature, or akin to Liberian coffee, its taxonomic determination must be suspect. A wealth of confusion exists in regard to this species, for it seems that forms of Liberian coffee have been called excelsa, or have been given specific names and placed erroneously in an excelsa grouping. Many of the so-called excelsa coffees may well be hybrids, for botanists have remarked on the extreme variability of progeny seedlings.

The author suspects that much of the material which has been called excelsa coffee in the Dutch East Indies, in Malaya and other countries, is not the true excelsa coffee at all.

The *Coffea excelsa* as first discovered and described by Chevalier was found growing, and depicted in his writings, as a large single-trunk tree forming a high canopy. It was found not far from Lake Chad on somewhat sandy soil in semi-arid country, and it is said also to grow wild in some of the drier northern forests of Uganda.

One cannot imagine *Coffea excelsa* thriving out of its element in humid regions of heavy rainfall. Neither can one imagine excelsa seedlings having the potentiality to grow into large trees, submitting themselves happily to acting as grafting stocks for other coffee species in such environments. For these reasons the author suspects that the so-called excelsa coffee used for grafting purposes, and, indeed, for hybridization, is a hybrid itself, or a form of Liberian coffee which would best be trained and pruned as a large multiple-stemmed shrub.

Time of Pruning for Coffee in general

ECONOMY

The majority of planters prune their coffee shortly after the harvest is over. They do this for two reasons.

It is just before and during harvest that the trees begin to suffer from exhaustion. There is considerable leaf fall and often severe die-back, so that the trees at the end of harvest may look like scarecrows. A lot of dead, diseased and obviously weakened wood is formed which is also doomed to die, and many a primary or a main stem has been broken by the pickers as they reached for the fruit. It is the desire to tidy up, to get rid of diseased and dead tissues, and bring the trees back into good shape that makes planters prefer to

(*a*) A fifty-year-old Arabian coffee tree in the region of Coatepec, Mexico

(*b*) A forty-year-old Arabian coffee tree in Mexico before the sucker growths are reduced in number

PLATE XXXVI

A twenty-year-old coffee tree in Mexico after the sucker growths have been thinned. With conservative growers, teaching must be progressive rather than autocratic at first

Plates XXXVII and XXXVIII are reproduced from Manual Practico del Cafeto en Mexico by courtesy of Licenciado Don Juan Rebolledo Clement President of the Comision nacional del Cafe

PLATE XXXVII

prune at this time. Moreover, because the trees have been greatly relieved of their burden, and are then bent on the renewal of sustaining leafage, many a plantation of coffee begins to make new growth at this time. Furthermore, experiment has shown that very light prunings are all that are required, and prunings of such a kind can surely do no harm no matter what time of the year. The question still arises, however, when is pruning most beneficial?

The second reason for pruning after harvest is, that a large and extra labour force has been built up to pick the crop, and it is at this time that some of the temporary employees can be persuaded to stay on for a while to accomplish many of the much-needed tasks which have awaited the completion of harvest. The more permanent and skilled employees can thus be spared for pruning the coffee.

APPROPRIATE PERIOD FOR THE TREE

Much depends on the climate of the neighbourhood: on whether the rainfall is evenly spread, whether the rains and the growth season follow on, or whether a spell of drought is about due. Much depends also on the state of the roots in the soil—as to whether they are in the midst of seasonal growth, or nearing the dormant season when their growth and action cease.

Coffee is an evergreen. Whereas a deciduous tree is truly dormant for a while, an evergreen shrub is never absolutely dormant—not if it is given an ideal environment and the amount of moisture it needs in the subsoil. Here is the crux of the matter. An evergreen may maintain its leafage by reason of the moisture it gathers from the subsoil, but it may, like coffee, have resting periods of growth because the surface-feeding roots are not active.

What, then, is the best time for pruning? Should we prune during a resting spell or during active growth? The tree is an evergreen and it grows in the tropics.

Physiologists talk of the period required for the ripening of flowering wood, and delve into the matter of the initiation of flower buds. These are initiated in series in the axils of the leaves on the primary branches, and what makes the whole subject most tricky is that these microscopical initiations may be influenced in two ways as they swell into full-sized buds and begin to fulfil their destinies. They may be influenced to form flowers, or they may be influenced to change and produce leafy shoots instead.

Pruning at the wrong time may bring about this change, just as the incessant puncturing of the young shoots and leaves by Antestia bug may influence many of the flower buds to produce multiple shoots instead. However, the pruning has to be somewhat heavy, and at a critical time to bring about such a result, and we have seen that a very light pruning is all that is necessary.

It would seem that pruning is best done when the tree has naturally begun to make new growth; not when that new growth is mature, and not when the buds of ripened wood are deciding whether to break out into blossom or new growth. The flower buds begin to spike with the first shower of the new season following a dry spell, so pruning should not be done before or during this time.

Hence, perhaps, common practice in deciding to prune soon after harvest is very nearly right. It must be remembered, however, that the trees are exhausted by cropping and require every green leaf to help them manufacture

more food to sustain the roots until they have made new growth. It is doubtless for this reason that experimental results have shown that only a very light pruning is advisable.

Mayne takes the opposite view,[11] for he says that the time for pruning is obviously when the tree has ample reserves of food, which, of course, it has not got at the end of harvest. He states that the operation should be undertaken when the trees are in good heart, which is normally their condition before a prospective good crop. In his opinion, an improvement in the shoot growth in a good year, will lead to an improvement in the crop prospects in the following light-crop year, and thus tend to smooth out the violent fluctuations in crop which take place in successive years. He is against undue treatment to encourage growth in the 'off' year, for this will only enhance the crop in the 'on' year and widen the fluctuation.

If theories and experiences are correctly interpreted, Mayne may be right in this respect. If pruning is done just before a good crop, it may throw many of the flower buds into shoots instead of blossom, thus reducing the crop in the good year; it may provide bearing wood for the next year and tend to even up cropping. It seems there is need for more research concerning the time of pruning and its effects in the various environments where coffee is grown.

The time and extent of pruning is likely to have a more noticeable effect in those regions where warm temperatures and short rainfall with distinct dry seasons are not ideal for Arabian coffee.

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Chapter XI

CARE AND MAINTENANCE

A Newly-Planted Field

CARE DURING EARLY LIFE

To obtain a field in crop at the earliest opportunity, and to avoid losing a wet season, it is possible to line and hole out the first block cleared, as soon as the terrace ridges have been constructed and consolidated to avoid erosion. If the ground has not been ploughed or dug over for the first time in order to extract the roots of trees and perennial vegetation, the holes must be generous in size. It will not be easy to plough and rake up and dispose of roots by mechanical means among the young planted coffee, and more hand labour will be required to cultivate and tidy up the squares that remain round each coffee plant. However, the task can be done, and the intervening spaces between the rows of coffee cleaned up afterwards.

Arabian coffee bears too early and takes about two and a half years to yield a sizeable crop if the environment is unsatisfactory. It is always a bad sign when Arabian coffee flowers too early, because a period of three or three and a half years indicates happier conditions, and a wait of four years is best of all, for one may then be sure that the temperatures are not too warm and that there are no influences forcing the trees to bear earlier than they should. Robusta coffee prefers warmer and more humid conditions, and it is not a good sign if the bearing of robusta trees is delayed for longer than two and a half to three years.

There is, therefore, plenty of time to carry out all the preparations for the first harvest, and to get the land in good order while the young trees are growing. Felled timber may be neatly stacked so that it may season for later use, old stumps and large roots may be dragged off the land and attention be given to any patches of noxious weeds which must be carefully eradicated within the first year. The land drainage system requires watching to check faults, and the contour ridges may need repairs, with extra soil dumped here and there to correct settling and bring them to the required height. Ultimately they will consolidate and require very little attention.

Weeds will grow apace. The soil must be covered and protected from hot sunshine and the pounding action of heavy rain. It is best to cover the planted area with a six-inch layer of grass mulch, for this will give the necessary protection, inhibit weeds and save weeding costs. The use of cover crops is unwise unless there is ample rainfall to make up for the moisture they draw from the subsoil. For the same reason temporary shade crops should not be sown near or between young coffee if the rainfall is erratic and below a total of about eighty inches per annum. A mulch is far more useful at this stage and it may be laid more thickly along the coffee rows.

TEMPORARY SHADE

Arabian coffee does not need shade during its early growth until it begins to bear; in fact, in ideal environments, it never requires overhead shade. Robusta

and Liberian coffees enjoy a fair amount of shade, and will grow better if they are given shade at an early age, in which case bananas may be planted in the middle of each permanent shade tree square. Bananas harmonize with coffee, and they appear to do no harm to robusta or Liberian coffee provided the shade is not allowed to become too dense. The bananas may be cut down, uprooted, and split up for mulching purposes when the permanent shade trees have grown big enough to give sufficient shade. They will have given crops of fruit for about two years, i.e., about three good bunches per stool. Despite the temporary shade, it is still beneficial to mulch the soil round the robusta or Liberian plants.

Bananas are not advised among Arabian trees, and the chapters on environment and shade trees will give all the necessary information regarding permanent shade. Most shade trees grow at a fast pace and are of sufficient size to give partial shade by the time the coffee begins to bear.

In regions where permanent shade is known to be required for Arabian coffee, it has become common practice to sow temporary shade crops such as pigeon peas, or tall-growing species of *Sesbania*, *Crotalaria* and *Indigofera*. *Leucaena glauca*, and other shrubby plants, are also used both for soil cover and temporary shade. That this practice may be harmful is shown by an experiment at Lyamungu, Tanganyika Territory, which was begun for quite a different reason. Plots on sloping land were treated in various ways to prevent soil erosion, with results as shown in the following table.

THREE-YEAR TEST.
Yield in cwt. clean Coffee.
Erosion in tons of soil.

Treatment	*Average yield of Arabian coffee*	*Erosion per annum*
Clean cultivation	2·93	1·82
Hedges of erect Crotalaria on ridges	2·63	1·07
Erect cover crop of Crotalaria alone	2·54	2·49

The erect cover crop gave the poorest results, and the experiment is summarized by saying that although some cover crops and live hedges may be useful as anti-erosion measures, they could not be adopted in the neighbourhood of Lyamungu, unless irrigation was available, because of their harmful competition for soil moisture. Yet the annual rainfall at Lyamungu is about sixty inches per annum!

It would seem that cover crops and temporary shade may, indeed, cause a moisture deficit in the subsoil during the drier months of the year, and if rainfall is erratic. The same might be said for weeds, because they must be harmful too, except during the wettest months of the year in a high rainfall area. Where the rainfall is below seventy-five to eighty inches, moisture conservation practices must be followed more rigorously. Contour ridging and mulches are the best means of doing this.

After a test covering six seasons, mulching and cover crop trials in Uganda showed that mulching gave better returns than clean weeding. In sequence,

clean weeding was superior to a permanent cover crop, and this in turn was superior to weed cover. The mulched plots were outstanding in appearance, because the coffee plants were a healthy dark green colour, and very vigorous. Weed-covered plots were outstanding in the opposite direction, the coffee plants being yellowish, very weakly, and producing few primaries and very little crop. It is said that 'the experiment stood as a startling ocular demonstration'. The yields were tabulated.

YIELDS OF FRESH CHERRY—CWT. PER ACRE.

Season	*Annual mulch elephant grass*	*Clean weeded*	*Cover crop*	*Weed crop*
1934–35 ...	30·6	29·6	9·4	7·8
1935–36 ...	102·6	105·6	40·4	20·0
1936–37 ...	113·2	72·8	75·8	64·4
1937–38 ...	125·0	118·2	83·6	60·4
1938–39 ...	99·0	55·8	54·8	35·6
Totals ...	470·4	387·0	264·0	188·2

N.B.—The cover crop used was *Centrosema plumieri Benth.*

H. C. Pereira of Kenya has stated (*E. Afr. agric. J.* 15, 4, April 1950) that in the drier areas which produce nearly half of Kenya's coffee crop, there is not sufficient rainfall to carry both coffee and weeds or cover crops. By permitting free weed growth during both the long and the short rains, and cultivating only twice a year, i.e., at the end of each wet season, crop yields were reduced 57 per cent in comparison with clean weeding.

CATCH CROPS

For the same reason catch crops may compete for the moisture supply, create deficits in the subsoil, and thus be harmful to the coffee in regions where the rainfall is short, even when the coffee trees are very young. Many people believe that 'surface rooting' crops occupy only the top layer of the soil to a depth of no more than one foot; this, of course, is a fallacy. Our well-known cereals, and crops such as beetroot, penetrate the soil and send down roots in search of moisture as deep as five and six feet or more. A planter forewarned about this must consider the risk, and judge for himself whether the 'slight' setback to the coffee may be more than offset by the returns from his catch crops. He must remember that small influences in the beginning may affect the building up of that strength in the young coffee bushes before they begin to bear, which will mean increased yields and better health throughout the life of the trees. So many experiments prove this to be the case.

At a spacing of 9 ft. × 9 ft. there is, of course, space between the young coffee plants during the first two years, and their root spread may not measure more than a foot beyond the tips of the branches. It is not the shading or the competition for nutrients which can be harmful, for it appears to be a matter wholly concerned with subsoil moisture. One must consider which crops

might be grown between the rows with the least possible harm. Certainly not Cassava or maize, neither would sweet potatoes be advisable. Two rows of ground-nuts, dwarf beans, or something of this kind might not do much harm where the rainfall is sufficient and satisfactory; but would such a thin sowing be worth while? In the author's experience the returns do not warrant the expense.

Some crops, especially grass crops, seem to have a depressing effect upon the roots of other plants beyond that which might be caused by competition for the nutrient and moisture supplies, possibly because of an antibiotic exudation from their roots. Maize is suspect, for the leaves of young coffee often turn yellow and look sickly when maize is inter-planted, in a manner which is not evident when tall weeds or other herbaceous plants grow thickly surrounding them. For this reason it is inadvisable to sow maize among young coffee. To protect and cover the soil and help to prevent soil erosion, there is no better means than mulching, provided a plentiful supply of mulching material is within easy reach. The East African authorities are beginning to advise planters to set aside a sufficient acreage of their poorest land on which to grow mulch material.

Mulching

MULCHING MATERIALS

The best and cheapest mulching materials are banana trash and Napier grass. It may be found useful to grow a fair-sized acreage of bananas to provide fruit or food to add to labour rations, or bananas of a suitable variety might be found profitable for local sale. In either case the cost of growing the banana mulch would then be reduced. The author would like to refer to mixed farming again and go on to talk of pig-raising to provide a rich manure to feed the bananas, but this would not come within the scope of this book. It is sufficient to point out that bananas might not be very costly to grow for mulch in consideration of the possible return. During their growth, the older leaves and the outer leaf-sheaths shrivel and form trash, and when the bunches are cut, the pseudo-stems must be cut down. They then provide a soft juicy material highly retentive of moisture, which may be split and slashed into pieces to provide mulch. Banana trash contains a high percentage of potash which is generally considered useful to apply to a fruit crop.

Experiments carried out in India, though not conclusive, and unfortunately discontinued, gave interesting results because the yields were against the potash treatments in the first year, whereas in the second year they showed improvement at the higher rate of application.[6] One wonders whether a build-up took place, and if the effects of the potash began to show in the second year, or whether there were seasonal influences at work. (*See* Table.)

Napier grass (elephant grass) *Pennisetum purpureum*, grows to a height of from ten to twelve feet in a thick mass of leafy canes. It is propagated by cuttings planted about two feet six inches apart in rows three feet apart, much as one would propagate sugar-cane, and since growth is fast, there should be material to cut within a year of planting. The plots of grass are perennial and everlasting, and produce a big tonnage of material per acre provided manuring is practised on each occasion when the grass is cut. Elephant grass responds well to organic manures, or to a balanced fertilizer using nitrate instead of

COFFEE RESEARCH SUB-STATION, CHETHALLI, COORG, INDIA.
INFLUENCE OF POTASH.

Treatment	*Yield per acre of Arabian coffee*			
	Ripe cherry in lb.		*Clean coffee in cwt.*	
	1950	*1951*	*1950*	*1951*
Control N + P but no K. ...	2,767	1,784	4·94	2·65
N + P + 40 lb. K.	2,484	1,667	4·44	2·48
N + P + 60 lb. K.	2,163	1,767	3·87	2·63
N + P + 90 lb. K.	1,907	2,300	3·40	3·42

ammonium sulphate. Provided the soil is well drained, and since the grass responds to manuring, it is not essential that it should be planted in the first place on the best soil. If Napier grass is cut young it makes excellent silage, or immediate fodder for livestock. The mature canes are useful for many purposes such as marker sticks, temporary wind-break fencing and roller blinds for shading nursery beds, a foundation for thatched roofs, and wicker tables for drying robusta coffee fruit.

The following figures are given for a 'time of cutting' test carried out at Lyamungu in 1940 and 1941 for Napier grass planted in 1938.

Weeks	*Tons per acre per annum*
10	62·9
12	52·5
14	60·4
16	66·1
18	55·6
20	63·6

Growth may vary in accordance with the time and amount of rain showers, but the figures show the yields that may be expected from a four-year-old field of the grass. At the research station they use the June cuttings for mulch, the September to November dry season cuttings for compost, and the December to March cuttings as fodder for livestock.

A grass similar to elephant grass in every way except one, and some small taxonomic details, is *Pennisetum haareri* Stapf. et Hubbard, named in honour of the writer who found it growing in thick pure stands in the neighbourhood of Bukoba district in N.W. Tanganyika. It is mentioned only because it differs from elephant grass in that it grows on a swampy wet soil which may form part of anyone's land and thus be made of use. If this grass is planted on a soil that is continually wet, it will provide as good and as much material as Napier grass.

Pereira and his colleague P. A. Jones have stated that the practical difficulties in regard to mulching large estates are admittedly great, but they may be overcome by energy, initiative and organization as may be seen on a number of progressive estates. Bush-clearing and stump-clearing of every spare acre so that the grass may be mown mechanically, the planting of

vigorous and bulky grasses in every spare corner, the devising of sleds or low-loading trailers for the transport of grass, or even the adaptation of binders to facilitate the handling of large quantities of grass—all this will render the act of mulching easier. In order to obtain the minimum four-inch cover over the exposed soil to within eighteen inches of the coffee trees, about twenty-seven tons per acre of newly-cut Napier (elephant) grass are required, wilted for one week after cutting. In addition to the conservation of moisture and the reduction in soil temperatures, such a mulch of Napier grass has been computed to give the equivalent of a dressing of 660 lb. per acre of phosphoric oxide, or about 2 cwt. bone meal or 2½ cwt. Seychelles guano. The nitrogen content of the sun-dried grass was approximately 88 lb. per acre, equivalent to over 3 cwt. sulphate of ammonia.

The operation of mulching could be considered less costly on this account were it not necessary to manure the grass plots to ensure a maximum supply in perpetuity. However, chemical fertilizers have a much better use when applied to the grass for mulching, and not only is mulching less costly now that alternate row mulching has been found the best, but the increased yields of coffee show a balance on the profit side.

THE BENEFITS OF MULCHING

The benefits to be derived from mulching have been proved beyond doubt during recent years, in Uganda, Kenya, and Tanganyika Territory, and this is not surprising seeing that wild coffee is a forest undergrowth where the ground is shaded and cool and often covered with a natural litter. Experiments in Uganda[9, 10] showed that mulching robusta coffee with a nine to twelve-inch depth of cut Napier grass encouraged the production of a crop that was three times that from manured plots, and five times that from the controls. After mulching had been carried out for some years it was found that surface soils with a lower *p*H value than others tended to become sticky under the mulch, and appeared to lose structure, yet there were no differences in the yields or observable health of the robusta trees. However, it was found better to mulch alternate rows, so that the intervening rows were rested for a year, and this immediately restored the soil texture.

The advantages of alternate row mulching are a reduction in cost, improved soil texture, less mulching material required, and less risk of fire sweeping through a plantation. Moreover, it has been shown in Kenya that yields may be increased, which would seem to indicate that a continual mulch may not be advisable on every kind of soil.[8]

KENYA MULCHING EXPERIMENTS.

YIELDS IN CWT. CLEAN COFFEE PER ACRE.

Treatment	*Average yield Arabian coffee for 6 years*
Box ridging	4·72
Complete mulching... ...	7·02
Alternate row mulching ...	7·63

KENYA MULCHING AND METHOD OF PRUNING EXPERIMENT.

YIELDS IN CHERRY PER TREATMENT.

Treatment	*Weight in lb. Arabian coffee Average 6 years*	
	Single-stem pruning	*Multi-stem pruning*
Box ridging	1,623	1,443
Complete mulch	2,369	2,499
Alternate row mulch	2,382	2,636

Note.—It appears that multi-stem coffee also benefits from mulching and that alternate row mulching is the best.

Figures provided by the Kenya reports show that no significant difference in yield occurs when the treatments are varied to (*a*) mulching between the rows, (*b*) mulching under the trees, and (*c*) a complete mulch, except that all three variants give much better returns than no mulching at all. When the yields of the separate years were examined, the fluctuation in yield from season to season was found to be much greater on the mulched plots than on the controls. It is said that the benefit of mulching appears to lie in the ability of the mulched trees to take advantage of a good season.

MULCHING TRIAL, KITALE, KENYA.

YIELD OF CHERRY IN CWT. PER ACRE.

Year	*Mulch between rows*	*Mulch under trees*	*Complete mulch*	*No mulch*
1942 ...	30·59	28·78	30·98	28·59
1943 ...	32·82	32·05	23·38	28·51
1944 ...	41·90	42·44	52·36	25·47
1945 ...	15·30	15·30	12·26	14·88
1946 ...	13·74	12·02	15·10	8·61
1947 ...	42·63	38·30	33·12	43·37
1948 ...	28·04	16·03	16·44	23·46
Totals ...	205·02	184·92	183·64	172·89

It must be remembered that the value of mulching may be emphasized where the rainfall is short, or where temperatures fluctuate between extremes. Mulching not only conserves moisture but shades the soil, lowers its temperature, and keeps the temperature more even. The results of experiments in Uganda and Kenya must be studied in relation to the fact that the rainfalls there are short, and the maximum temperatures rather too high for Arabian coffee in the regions where the experiments took place.

At Lyamungu the climatic conditions are somewhat better for Arabian coffee, but the rainfall is erratic and the tabulated results of a ten-year trial show the same significant results.[7]

LYAMUNGU MULCHING TEST.

YIELD IN CWT. CLEAN COFFEE.

Treatment	*Average annual yield of Arabian coffee*
Control without mulch	7·71
Mulched with Napier grass at rate of 80 lb. per tree	8·69
Mulched with banana trash at same rate	8·99

NITROGEN CONTENTS OF THE SOIL

A report by the soil chemist at Lyamungu gives interesting information about the nitrogen status of mulched soils.

NITRATE NITROGEN IN PARTS PER MILLION OF SOIL.

Treatment	*A.*	*B.*	*C.*
Banana mulch	37·0	18·0	37·0
Grass mulch	23·5	14·0	18·0
Bare soil	18·0	12·5	21·0

The fall in nitrate content from A to B was the result of thirty-three millimetres of rainfall. C represents the conditions three weeks later after a period of warm weather with occasional light showers. Banana trash resists decomposition and is a more effective soil cover, whereas the elephant grass mulch begins to break down earlier and thus the nitrogen content of the soil is depressed for a while.

FOR AND AGAINST MULCHING

The objections to mulching are the expense, and the danger of fire. Banana trash does not burn readily and there should be little risk from fire if alternate-row mulching is practised, and provided an efficient fire belt is kept cleanly cultivated surrounding the estate. This is very necessary in regions where the natives set fire to the natural herbage in the dry seasons. Someone should be deputed to keep a watch for such fires, so that burning against the wind may be begun to avoid the risk of sparks crossing the fire belt. As for the expense, one cannot 'make omelettes without cracking eggs', as the old adage goes and provided there is systematic working, the money spent on mulching is amply returned by additional yields over a period of years. Combined with contour terrace ridges, mulching is the finest method known of stopping erosion.

TIME OF APPLICATION AND QUANTITY OF MULCH

Results at Lyamungu indicate that a mulch does not appear to be so effective when applied at the end of the rains, and that better results may be ob-

tained if it is laid just before the long rains begin. If a light mulch is given of forty pounds of Napier grass per tree, the yield of coffee can be increased beyond that gained by a heavier mulch at an eighty pounds rate, despite the fact that a lighter mulch often ceases to give an effective soil cover by the onset of the dry season.[2]

Mulch	*Average yield over period of years*
0.	4·62
40 lb. per tree	4·92
80 lb. per tree	4·71

One may interpret these results as meaning that the forty-pound rate is sufficient to conserve moisture and bring about a status of 'field capacity' in the subsoil, which is all that is required to carry the coffee through the following dry season; and also that the decomposing mulch allows the top soil to become drier in the dry months when the trees are less active and do not require excessive moisture in that part of the soil where their feeding roots are situated. In fact, a very moist top soil under a heavy mulch during the dry months may cause unbalance, and throw the trees into leafage rather than fruit, or hinder aeration and a consequent rise in the nitrogen status. This may also explain why alternate-row mulching has been found to provide better yields. Coffee often seems to respond in a manner opposite to that which might be expected, and the reasons might be summarized by stating that we are dealing with an evergreen and not a deciduous tree. The long growing season with tropical temperatures results in a larger water requirement than for deciduous orchards. Though evergreen orchards require moisture throughout the year they depend on the subsoil to provide it during dry spells.[1]

WEEDING AND CULTIVATION

A fresh mulch inhibits weed growth for some while, but as it breaks down a few weeds will begin to break through. Some of the joints of the elephant grass cane may root and sprout in wet weather if the material is not sufficiently wilted beforehand. Mulches require a kind of reshuffling or scuffling from time to time, and if the work is not delayed too long one man can accomplish a very considerable area in one day. The headman or ganger supervising the laying and care of mulches should be made partly responsible for taking note of, and reporting (*a*) accidents to, and deaths of young coffee plants, (*b*) any particular insect pest or incidence of disease which he has been instructed to look for. Elephant grass canes with tags of red or yellow bunting might be carried by him, and fixed upright to flag a new vacancy, or the frass of a borer beetle attacking an old tree. It has been reported that cut worms are more active and likely to do more damage to young coffee which has been mulched.

VACANCIES MUST BE KEPT FILLED

During the period of growth before a coffee plantation begins to bear, and before the shade trees are giving much shade, it is imperative to fill up gaps caused by mishaps to young trees. It is wellnigh impossible to do this later

among older trees and under shade when root competition has grown keen, because only a drawn and spindly growth would result. At Lyamungu with trees trained to the single-stem method of pruning, 'Kent's' coffee is said to overlap at four years old when planted 9 ft. × 9 ft. apart. Failure to establish trees during the early years will leave gaps and reduce the yield per acre during the lifetime of the orchard.

Other Methods of Cultivating

CLEAN WEEDING

Some planters still believe in clean weeding, in constantly scuffling the soil surface to obtain a fine tilth. The old myth that a dust mulch prevents the evaporation of moisture has been exploded, though to assist the natural increase of nitrates in the surface soil, it is better not to have a hard crust on the surface such as that which forms on a very friable soil when it has been wetted by successive showers and then sun-baked. The constant cultivation of a bare soil in the tropics alters its structure and destroys its porosity. The pores are then easily closed by rain, so that the water runs off the land instead of soaking in, thus it is unable to reach the subsoil in sufficient quantity to make up for deficiencies created during the dry season. Because more water runs off the surface, sheet erosion and gully erosion begin.

Few would cultivate and keep a bare soil without the protection of contour ridges nowadays. If hand-hoeing or hand-cultivating is done it should be done uphill, so that each scrape of the hoe builds up a little ridge at right angles to the slope. Mechanical cultivation which forms ridges is accomplished along the contour, and there is no real need to cross-plough and cross-cultivate in an orchard of coffee which, when the trees are three years old, should never be cultivated again. Instead, the orchard should be treated like a forest, where the feeding roots are in the surface soil and should not be disturbed.

Cultivation Test, Lyamungu.

Treatment per annum	*Average yield for 14 years in cwt. of clean Arabian coffee per acre*
No cultivation	5·13
West Indian chopping hoe ...	5·61
Envelope forked	5·40
Trenched	5·04
Forked chopping hoe	6·18

Note.—The trees were pruned to a single stem for six years, then converted to multiple stem. There were no yields for two years.

A Comparison of Methods

A trial has been carried out over a period of fourteen years at Lyamungu to see what effect on yields there may be if the soil is cultivated in different ways.

Though there is no significant difference in the yields, the results seem contradictory. Cultivation without too much damage to the roots may be expected to give a slight advantage over a bare soil that is not cultivated. However, on account of the aeration favouring nitrate production, and since a bare soil cannot be likened to the conditions appertaining to a forest, it is a pity that a comparison was not made with a mulched uncultivated soil.

Box-ridging, Tie-ridging and Silt pits

Planters who have not taken care to protect their land from erosion in the beginning, and find later that sheet erosion is taking its toll, have tried to stop this by digging silt pits. These are elongated pits between the rows of coffee at right angles to the slope, usually staggered by angular spacing. The spoil is thrown on the lower side and arranged to trap more of the water carrying the silt as it flows downhill. Sometimes these pits are filled with weeds and closed in, while new ones are dug between the old ones.

Box- and tie-ridging are two words meaning the same thing, i.e., a continuous system of narrow-based ridges at right angles to the slope with cross-ridges every three, four, six or eight feet. This form of erosion control is in favour in native areas of Tanganyika Territory where the rainfall is not heavy, and where the people have not the gumption to grade their ridges properly or construct storm drains in safety. They are trained to judge levels with their eyes, and hence if the grade they choose is too steep the cross-ridging checks the flow and the scouring which may take place. This is the theory of the scheme which does not always work out in practice.

The objection to this system is that the land is pock-marked throughout with narrow ridges and ditches, holes and spoil. The difficulty of walking over such land can be imagined, and like the silt pits, the hollows soon get shallower as they fill with silt. The work of constantly digging out the silt and reconstructing these systems is tiresome and heartbreaking, hence it is often neglected with dire results. An ordinary shower of rain will then fill the shallow depressions with water which overflows, carrying everything downhill, so that a hillside is scarred with a disastrous loss of top soil. Freshly dug silt pits or tie-ridges are subject to the same peril in the event of a freak storm which is bound to occur sooner or later. The author has seen these systems tried again and again during more than twenty years' experience and he cannot condemn them too severely except for arid country on very gentle slopes. It often happens that a young man has a bright idea and evolves such a system for himself. Thinking it new, he wastes money putting it into practice and is surprised later on to find that it has been tried already a hundred times and found to be of little use. A soil chopped into a mass of holes and little ridges must dry out rather more than a flat surface, albeit the hollows will help to conserve more of the moisture which falls as rain in an arid district, and allow it to reach the subsoil. Coffee, however, is not planted in arid country.

Pruning

Selection and Training of Pruners

As the young coffee begins to grow it will soon need training to one or

other of the pruning systems which are fully discussed in Chapter X. As has been stated, the single-stem system of pruning requires more skill than any other, and this question of skill is important no matter what system is used.

A practised and trained planter knows exactly how he would prune each coffee bush, but he must leave the task to others, and no two men will prune a bush in exactly the same way. Some will tend to prune lightly, others rather more heavily, while an occasional employee will profess to a skill which he does not possess at all. There is the danger that some employees, who have been trained to follow some other system elsewhere, may try to teach the planter his business. The headman of the pruning gang must be a conscientious and trustworthy man, and, in addition, the planter himself must supervise the pruning gang as closely as possible while his trees are being pruned. Proper pruning knives and pruning saws will be required and both must be kept sharp. Secateurs cannot pare off a saw-cut, neither can they make a clean cut; they soon become unserviceable in constant use and they are expensive to issue in lots of fifty or more. The pruning gang requires careful training before a start is made.

THE TIME TO PRUNE

When the sap is not rising is the best time to prune a tree, and when there are indications that it has recovered from a period of exhaustion, perhaps when the trees have begun to make fresh leaves following the harvest. If the young trees have not yet borne a crop, the best time would be towards the end of the wet season, when the new flush of growth has ceased.

A time-of-pruning test has not been continued for very long at Lyamungu, but the tabulated results indicate that pruning soon after harvest is the best time.

TIME-OF PRUNING TEST.

ARABIAN COFFEE.

Time pruned	*Average yield over 3 years, 1949–51*
	Cwt. of clean coffee per acre
During month in which harvesting was completed:	13·11
One month later	11·46
Two months later	9·97
Three months later	9·93
Four months later	9·00
Five months later	8·27

SEVERITY OF PRUNING

Next comes the question of how much to prune, and this concerns Arabian coffee and single-stem pruning particularly. Experiments have been carried out since 1946 at Chattadhulla (Coorg) India and it will be seen in the tabulated results, which have been arranged somewhat differently, that no pruning at all appears to have given favourable results.

TIME AND SEVERITY OF PRUNING TEST.

5 YEARS 1946–51.

Treatment	*Average yield of ripe cherry in lb. per acre*	*Total yield in lb. per acre*
No pruning	2,093	10,465
Light pruning in hot season	1,981	9,907
Light pruning in wet season	1,989	9,945
Medium pruning in hot season...	1,993	9,967
Medium pruning in wet season	1,947	9,734

Results of pruning would, of course, largely depend on whether the Arabian coffee trees bore most of their crop on their young wood or on their old. The trees in question were under natural shade. The test would seem to indicate that beyond de-suckering, and cutting out crossing, broken, and dead branches, very little pruning is desirable. The system of single-stem pruning is undoubtedly unnatural, for, whereas the whole nature of the coffee tree is to go on growing at the tip into a tallish tree, sacrificing its lower branches as it grows taller, this system of pruning demands that it should be kept topped at about five feet tall, and that the lower branches should be preserved. Doubtless the roots and the health and yield of the foreshortened tree depend on all the leafy branchlets that can be maintained and they respond adversely if any are pruned away.

MANURING

ORGANIC MANURING

The Research Department of the Indian Coffee Board report no significant results gained from the application of organic manures to Arabian coffee in comparison with control plots that were not manured. A response appeared to take place in some years, but in general there was none to warrant the

COMPOST AND MULCH.

SINGLE-STEM TREES. UNSHADED.

Treatment per tree	*No compost*	*Dose. 4-gallon container filled with compost*	*Dose. 2 containers filled with compost*	*Average yield*
No mulch	8·68	9·26	9·42	9·12
40 lb. dried Napier grass mulch	8·84	9·52	9·43	9·26
80 lb. dried Napier grass mulch	8·78	9·00	8·79	8·86
Average yield	8·77	9·26	9·22	—

expense of using such manures. It was believed that the amount of mulch that was being added by the shade trees provided enough plant food to produce an average crop.

At Lyamungu tests with Arabian coffee have been continued over a period of ten years and the tabulated results are interesting. The yields are given in cwt. of clean coffee per acre.

A small quantity of compost per annum together with a light mulch appeared to give the best result—0·84 cwt. clean coffee per acre more than the plots which received nothing. It is shown that a small quantity of compost has a feeding value, but it must be remembered that the plots were unshaded and that a leaf fall from shade trees might give the same results.

COMPOST AND NITROGEN.

SINGLE-STEM TREES. UNSHADED.

Treatment per tree	*No nitrogen*	*Sulphate of ammonia*		*Average yield*
		1 oz. 1940–42 *2 oz. 1943–45* *3 oz. 1946–49*	*2 oz. 1940–42* *4 oz. 1943–45* *6 oz. 1946–49*	
No compost ...	8·63	9·12	8·56	8·77
Dose. 4-gallon container filled with compost ...	9·50	9·09	9·20	9·26
2 containers filled with compost	9·43	9·14	9·08	9·22
Average yields ...	9·18	9·11	8·95	—

It would appear that the continued application of sulphate of ammonia has a depressing effect, and it is again shown that small amounts of compost give slightly better yields. A gain of nearly one cwt. of clean coffee per acre is obtained by giving a small amount of compost per tree with no nitrogen.

Of the composts used at Lyamungu, the following analysis was made.

	Average per cent per cwt.	*Variation per cwt.*
Dry matter	64·50	50–90
Composition of dry matter:		
Organic matter	17·00	12–27
Nitrogen	0·73	0·50–1·17
C/N Ratio	13·50	13–13·50
P_2O_5 Total	0·83	0·69– 1·00
P_2O_5 Available	0·25	0·03– 0·40
K_2O Total	1·57	1·12– 1·95
Exchangeable	1·38	1·01– 1·81
Acid Soluble Ash	17·80	9·60–30·10
Insoluble Silica	51·60	42–62

An experiment was designed at Lyamungu to test the effect of boosting compost with various combinations of chemical nutrients, such as N, P, K, NP, NK, PK and NPK. These were added to the raw materials, but the rate of decomposition was not affected. The addition of nitrogen appeared

to be wasteful, because the final product contained hardly any more nitrogen than the untreated compost. Potassium sulphate gave an increase of between five and fifteen per cent of potash, but it did not increase the amount of exchangeable potassium, while rock phosphate doubled the percentage of P_2O_5 and increased the readily available P_2O_5 by 50 per cent.[7]

MAKING COMPOST IN COMMERCIAL QUANTITIES

There are several ways of making compost, and various authorities advocate one or the other. For instance there is the pit method, whereby the materials are placed in layers in a large pit, watered as they are put in, and then covered by some sort of shade to protect them from hot sunshine or heavy rain. The mass is left until decomposition is complete, and it is argued that very little of the valuable volatile substances are lost, nor does the material dry out by exposure at the sides to the air.

In practice it is a means of making silage too hopelessly rotten to give to livestock, so it is called compost instead! The labour of digging the pits is considerable, and the task of digging out the compost from below ground level is not only backbreaking but wasteful of effort. Moreover the breakdown of the material is slow. In the making of silage, wilted but green and succulent material is pressed down tightly in a pit so that air is excluded, and no extra moisture is added. When making compost the material must be thoroughly wetted but properly aerated.

For compost-making the bulk of the material should be soft vegetation such as weeds, grass, straw or Napier grass tops; in other words, herbage in general, but not woody materials with high percentages of lignin. If the Napier grass has grown into tall canes it is helpful to chop it into short lengths in a chaff cutter, so that the pieces will lie closely together.

Compost material is laid in loosely trampled layers a foot thick, well watered, and with some starter material heavily sprinkled between the layers, such as fresh farmyard manure, or sewage slurry. Urine from cattle byres is most valuable if this can be saved in tanks and used for wetting the materials. Any other materials such as wood ashes, coffee pulp, coffee parchment husks, or household refuse may be added in thin layers, but it is not necessary to add lime, and nitrogen salts may be wasted and serve no useful purpose in the tropics.

It is useful to build up stacks in this manner about eight feet square and leave the top of each stack flat. Decomposition is rapid in the tropics, especially if the stacks are warmed by the sun, and not shaded, though it is wise to enclose the compost yard with some form of windbreak. Within a few days a stack will heat, begin to steam and sink in the middle, when it should be turned, rebuilt, and the materials well mixed.

A stack may need turning twice at proper intervals, and when this is done the drier outer materials are pulled to the centre and moistened, but not drenched with water. The top layer serves as shade, and when the stack is ultimately ready for use, any dry material is thrown aside for building up into a fresh stack. To arrange expensive cover and special shade is fastidious, uneconomical and bothersome, though it assumes the proportions of a fetish with some authorities. A flat top to a stack saves watering because the natural rainfall is used to help moisten the materials. The author has made many hundreds of tons of compost in this manner.

Alberto Correa in a note on the preparation and utilization of coffee pulp in the *Revista de Agricultura, Industria y Comercio XXXV* 2. 1944 gives the following analysis of coffee pulp.

COMPOSITION OF FRESH PULP.

	Percentage
Moisture	60·00
Organic material	38·12
Minerals	1·29
Nitrogen	0·59

COMPOSITION OF THE ASH.

	Percentage
Phosphoric acid	10·33
Potassium	52·99
Calcium	3·80
Magnesium	7·60
Sulphuric acid	3·27
Chlorine	0·82
Sodium Silica, Iron Oxide, etc. ...	21·19

Compost is ready to use when the material smells and looks like farmyard manure. It should be spongy and greasy when squeezed but not wet, and to generalize one might say it should be two-thirds decomposed with all the strawy materials well rotted. Many people allow it to break down until it is not much more than an inert earthy mass, by which time a great deal of its value will have been lost. Compost should be spread and turned into the soil without delay, or spread and covered at once by an ordinary mulch.

Woody materials ought not to be added to compost until they have decayed to the consistency of tinder, and sawdust should be stacked by itself and wetted with urine or sewage slurry. It takes time to decompose, and it should not be mixed with ordinary compost materials until its disintegration is well advanced. In the event of there being no starter material such as farmyard manure, compost from a former heap may be used provided it is at the stage when it is ready for use in the field, i.e., when it is still warm and greasy and filled with life.

To facilitate the making and turning and transport of compost in quantity there are several considerations to bear in mind. Firstly the 'yard' where the compost is made should be roomy and conveniently situated for the collection of materials, i.e., near livestock pens, near a supply of water, near the fields of Napier grass or source of bulk material, and perhaps near the factory premises where coffee pulp and coffee husks are procurable. Compost making should not be neglected because the coffee does not appear to respond too readily to compost manuring. Compost is useful for a hundred and one purposes on a large estate; materials accumulating should not be wasted and dressings of compost will help to keep a soil in good heart, in other words of good texture.

If it is at all possible, the mixing yard should be arranged on a slope so that floors at various levels may be constructed with a ramp against the lower floor to facilitate lorry loading. Floors should be of hard-beaten earth, brick or

concrete, and the fresh materials gathered and stacked at the top level. In turning and reforming stacks it is always easier to throw material downwards from one level to the next, and a pusher to simulate a bulldozer may be improvised for a tractor.

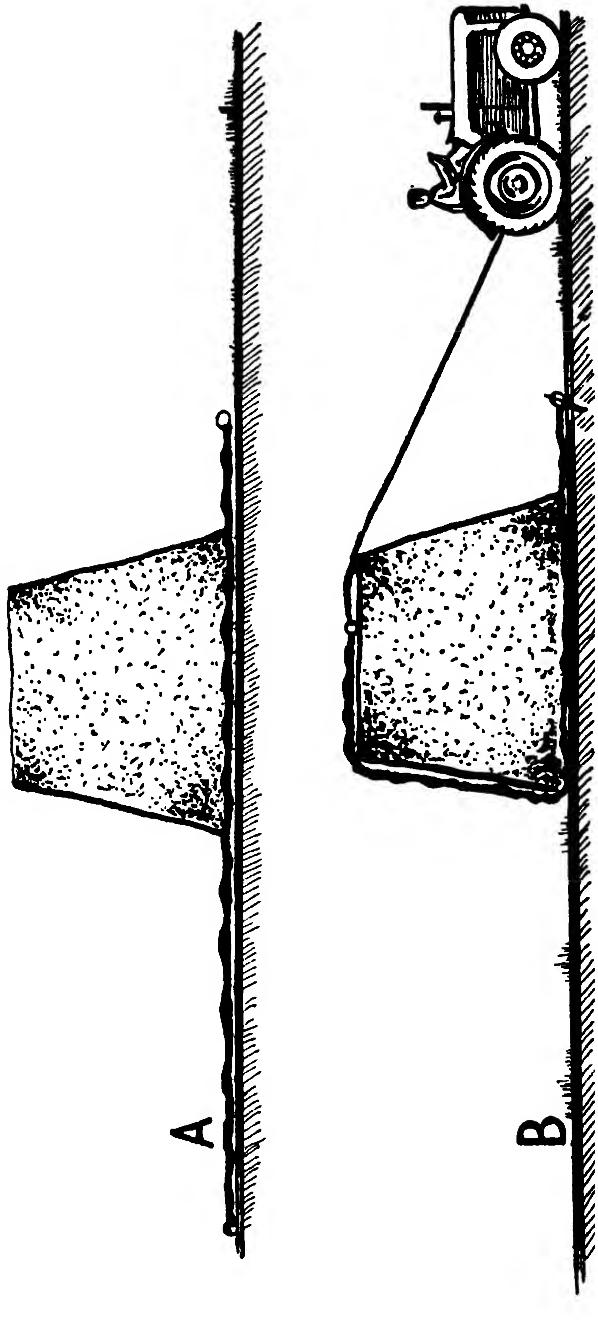

FIG. 29.—(A) Compost heap resting on chain matting. (B) Preparations made to turn the heap. One end of the chain mat has been fixed to the ground with firm stakes. The other end has been taken over the heap and attached to a bar, which in turn is attached at its centre by rope to the tractor. As the tractor goes forward the heap is rolled, aerated, and dumped in a new position.

Every possible use of mechanization to save labour must be devised, and a useful method is to stack material on chain netting and to roll it from one place to another, in which case the rolling action may almost be sufficient to re-aerate the mass and eliminate the task of turning by hand. The chain net is fixed to pegs along one edge. The other edge beyond the compost stack is lifted against the stack, attached to ropes laid over the stack and fastened to a tractor. As the tractor moves so will the mat roll the stack over (*see* Fig. 29). The same principle can be used for rolling materials out of lorries at the delivery end, if mats and a tractor are readily available.

FARMYARD MANURE

Rich farmyard manures are seldom procurable in sufficient quantities to apply to large acreages, and even if they were, the chances are that they would not increase yields to any significant extent, for there is a strong likelihood that they would encourage a leafy and soft growth at the expense of fruit. One must remember, however, that the results of experiments in any one country may not be gained elsewhere and may vary with altered environments. It may be assumed in general that the yields given by the application of bulky concentrated organic manures are not likely to compensate for the expense of preparing and spreading them, and that they would be found of greater value in application to plots of Napier grass or bananas grown for mulching purposes. It may also be assumed that part of the benefit derived from the application of bulky organic manures is found in their moisture-conserving properties as a mulch and their beneficial action in preserving soil texture rather than their feed value.

CHEMICAL MANURES OR FERTILIZERS

To return to Indian research, the following eleven-year test has been carried out at Balehonnur (Mysore). The coffee used was 'Kent's' variety, and the treatments given were: nitrogen at the rate of 20 lb. per acre 1941–49, and 40 lb. 1950–51; nitrogen plus phosphorus P_2O_5 at 30 lb. per acre; nitrogen plus potash K_2O at 40 lb. per acre; and all three; these were matched against controls with no treatment. The yields are given in lb. of ripe cherry per acre.

MANURIAL TEST AT BALEHONNUR

Treatment	*Average yield 11 years*
Nil	565
N	691
N + P	697
N + K	771
N + P + K	802

At first glance it seems difficult to understand why a continual application of nitrogen has not had a depressing effect, as it seems to have had in other tests, but much becomes plain when it is discovered that the nitrogen was

applied as ground-nut oil cake to the extent of 75 per cent while only 25 per cent was sulphate of ammonia. Various other disturbing factors were introduced, such as a dressing of half-a-ton per acre of hydrated lime in 1943 to counter acidity, and the provision twice a year of 5,000 lb. per acre of a dry leaf mulch to stimulate leaf fall because the shade was provided by bamboo slats. From 1945 onwards, coffee husk ash was substituted to give the calculated amount of K_2O, and considering everything, the results were not very conclusive.

At Lyamungu, preliminary pot culture experiments were carried out in 1936 to observe the symptoms in Arabian coffee of so-called deficiency diseases. Pots containing sterilized sand were planted with Arabian coffee seedlings of uniform size and kind with six leaves each. Each group consisted of four trees; one group received a complete nutrient, another lacked nitrogen alone, a third was given no potash and the fourth no phosphate. Within each group, two seedlings received a special nutrient consisting of copper, manganese and boron. The nutrients were applied three times a week, and the special nutrient once per fortnight. Distilled water was given on the remaining days and the pots were leached every fourteen days.

The first symptoms of abnormal growth were shown by leaves of the potash-deficient series after sixteen days, and these consisted of a yellowing of the leaf margins of the older leaves, beginning at the tips and spreading along the margins and inwards towards the midribs. In nearly two months the edges had become brown, and a fortnight later half the leaves had become brown and papery in texture.

Within forty-seven days the nitrogen-deficient series had become chlorotic, and this continued and caused leaf-fall, while the new leaves grew slowly. As for the phosphate-deficient series there were no definite symptoms even after one year.

Of the four plants which received the complete nutrient, the two which received the special nutrient in addition made a normal growth, while the other two were stunted. There was nothing like so much difference observable in the group without potash, except that the two plants which received none of the special nutrient were a little more compact and stunted. Those that lacked nitrogen grew into poor, spindly, insignificant plants, and the only difference the special nutrients made was to reduce the leaf fall. Of the phosphate-deficient group, even when the special nutrients had been applied, there were no true differences between the plants other than those which might be inherent. The nutrients used were as follows:

Complete nutrient solution	*Grammes*
Potassium nitrate	6·0
Calcium nitrate $Ca(HO_3)_2 4H_2O$	1·4
Di-potassium mono-hydrogen phosphate ...	1·0
Calcium sulphate	2·0
Magnesium sulphate	3·0
Sodium chloride	0·5
Ferric chloride	0·4
Rain water to one litre.	

One litre of concentrated solution was diluted with nine litres of rain water before application.

Special nutrient	
	Grammes
Copper sulphate $CuSO_4 5H_2O$	0·01
Manganese sulphate $MnSO_4 7H_2O$	0·01
Boron hydroxide $B(OH)_3$	0·0112

One litre of the above concentrate was diluted with nine litres of rain water before application.

S'Jacob, J. C., carried out experiments regarding the nutrient requirements of coffee over a period of three years and his results are recorded in the *Archief voor de Koffiecultuur in Nederlandsch-Indie* 12e. No. 1:2:48 March 1938. He found that only Shive's solution gave good results and his findings are tabulated.

	Deficiency	*Excess*
Nitrogen.	Very small plants with yellowish-green leaves. Length of root increases with a weaker solution.	Expected results did not show.
Calcium.	Severe root and leaf damage. Early death of plants.	$CaCl_2$: No harm. $CaCO_3$: Leaves chlorotic. Acidity of solution decreases, diminishing available iron.
Potassium.	Difficult to demonstrate. Edges of mature leaves turn greyish and become dry.	Leaves marbled and pale yellow. Older leaves die off earlier. Roots short and thick.
Phosphorus.	No result.	No result.
Magnesium.	Typical leaf spotting in zones where tissue is chlorotic. Remainder of leaves healthy.	Very harmful. Plants weak, slightly chlorotic. No characteristic symptoms.
Sulphur.	Very small plants with yellowish convex leaves of thin texture.	—
Sodium chloride.	Very typical. Margins of leaves reddish-brown and dry. Leaves convex and hang vertically. Damage caused by sodium-ion.	—
Iron.	Leaves show chlorosis with pale green veins.	—

In a second series of experiments ammonium salts were used as a source of nitrogen, and it was found that severe and typical symptoms resulted when the *p*H was not kept at a constant value. The distal leaves became convex and yellow with dark green banding along the veins, whereas the lower leaves obtained greyish-brown edges which did not dry out but remained pliable. The foliage was chiefly damaged whereas nitrates, he states, affect the roots. If the *p*H is kept constant between 4·5 and 5·0, the coffee grows as well with ammonium sulphate as it does with nitrates. Ammonium salts are harmful when the *p*H is at lower values.

SOIL NITROGEN

A prolonged study of the soil nitrogen and of its leaching during rain has been made at Lyamungu in conjunction with Arabian coffee. The soil there is a red loamy clay, and the following variations in the nitrate-nitrogen content of the top soil were found to occur in relation to rainfall, expressed as parts per million of oven-dry soil.

Date	*Clean-weed plots*	*Under cover crop*
1st October 1935	35·0	11·0
1st November "	41·5	16·0
15th December "	53·0	27·5
7th January 1936	15·0	5·5
15th February "	26·0	7·5
16th February "	3·5	4·0
6th March "	8·0	5·0
20th March "	16·5	9·5
7th April "	7·5	6·0
22nd April "	2·0	2·0
18th May "	1·7	1·6
1st June "	1·2	1·2
8th June "	2·3	2·8
22nd June "	2·6	4·6
29th June "	2·1	4·3

From April to early June, the amounts of nitrate were at their lowest ebb on account of heavy rainfall in April and May, the low temperatures and excessive moisture. As moisture conditions and soil temperatures become more favourable, nitrification proceeds apace until December, and since rain is very occasional during this period it is insufficient to cause leaching into the subsoil. At the end of December three inches of heavy rain caused such a leaching with a fall in concentration of nitrate in the top-soil in early January, after which nitrification began again. A four days heavy rainfall in mid-February caused another fall, and this shows how the nitrate content of the top-soil can be drawn on a graph to assume a curving wave-like line up and down in relation to the rainfall.

In the Northern Province of Tanganyika Territory where Lyamungu is situated, soils are so well supplied with mineral plant foods that available nitrogen and moisture are likely to be the limiting factors in plant nutrition.[7] Investigations were made to discover the fate of ammonium sulphate after it had been applied to a Kilimanjaro soil during the middle of the long rains. The soil is neutral in reaction, rich in bases and phosphate, and fairly rich in humus.

Applied at the rate of six cwt. per acre on the 6th May when most of the soil nitrate had been leached to a depth of four or five feet by the April rains, the plots were kept weeded but not cultivated. Subsequent weed growth was negligible. Samples of soil were taken periodically for the determination of ammonium ion and nitrate ion.

It was found that very little of the fertilizer was leached as such. The ammonium ion is fixed in the surface soil and thereafter converted into nitrate, and it is the nitrate which is liable to be leached downward into the subsoil. During thirty-seven days while twenty-five inches of rain fell, nearly all the ammonia was converted into nitrate and most of this was leached into the subsoil.

THE FATE OF AMMONIUM SULPHATE ADDED DURING RAIN

Days after application of sulphate of ammonia	*Rainfall from date of application*	*Percentage of additional nitrogen*		
		Remaining in surface soil as		*Leached*
		Ammonia	*Nitrate*	*Ammonia or nitrate*
11	14·5 in.	83	7	10
24	20 in.	23	22	55
37	25 in.	2	9	89

THE DEPTH TO WHICH THE ADDED NITROGEN WAS LEACHED

Depth of soil sample in inches	*Percentage of added nitrogen found in form of nitrate*
6	9
6 – 12	6
12 – 18	11
18 – 24	21
24 – 36	42

The natural replenishment of nitrate in the top layers of soil after the long rains is slow, and most tests have shown a significant response to applications of nitrogenous fertilizers at this time of the year. As is stated in the 1937 and subsequent reports from Lyamungu, one of the strongest indications of economic value is the soundness of an application of sulphate of ammonia near the end of the long rains, and more especially in very wet years.

Great care must be exercised, however, to see that sulphate of ammonia is not given in frequent or too heavy dosages, since continual use is known to increase soil acidity. Experimental plots which started with a soil reaction of *p*H 6·4, ended with a *p*H 5·3 value after heavy applications of sulphate of ammonia for three years in succession. The corresponding reduction of exchangeable bases was from 18·3 to 13·7 milligram equivalents per cent, i.e., twenty-five per cent of the exchangeable bases of the surface soil were removed in three years. It is obvious that nitro-chalk or sodium nitrate should be used alternatively with sulphate of ammonia if there is danger of the acidity value reaching beyond a *p*H of 4·5.

Nitrogen fertilizers need not necessarily be given every year at the end of the long rains. When the coffee trees are bearing a heavy crop which is considered to be too large, an application of nitrogen has been found to help them bear the crop without too much exhaustion and thus avoid the necessity of stripping to reduce the crop.

Tonic Spraying

It has been discovered that strange physiological disorders or growth peculiarities may affect crops in certain regions caused by the lack of one or more of the essential 'trace' or minor elements in the soil, or in fact by excesses of such minerals which upset the delicate balance of plant growth. There may be berry drop, leaf chlorosis or leaf fall. Excesses require drastic treatment to neutralize them wherever possible, but deficiencies of trace elements can be controlled more easily and in particular by spraying.

First there must be correct diagnosis, and this is a task for research of a highly specialized kind, beyond the capabilities of the commercial producer. Then comes the necessity for advice in regard to the formulation of the correct dosage. Cures have often been found, and so finely balanced are some of the trace element requirements that it is safer to spray the plants with very dilute solutions rather than add the elements to the soil. The foliage of plants has been found sufficiently absorptive; the deficiency is corrected immediately, economically, safely and without wastage.

The fact that such minor nutrients can be applied with such success to the leaves has led research workers to experiment with the use of the major nutrients in the same manner for special purposes, i.e., to help peach trees recover from winter damage; to help bigger crops of fruit to set and so on.

The value of such sprays has been their immediate absorption and effect, and it is quite possible that an N.P.K. mixture in the right proportion and dilution would be helpful if it were sprayed on coffee during certain times, i.e., when the fruit is setting and ripening, or when trees are exhausted and starting to recover.

When nutrients are sprayed on to foliage, very little is lost if the task is done carefully, whereas when they are applied to the soil they must be used in much greater quantity to have any noticeable effect; percentages are wasted on intervening spaces or on account of leaching during rain. There is also the fixation which takes place, and reactions which change and render chemical manures not so readily available. Modern research has discovered many new lines of inquiry which must be followed and thoroughly explored before we can say that we know all there is to know about the care and production of any crop.

It has been mentioned that coffee is a short-day plant, and may be influenced by the lengths of daylight and darkness, although this does not seem to have been investigated fully. This is a new field, just as booster spraying with the major nutrients is far from being fully investigated; also the use of weed-killer sprayers on all the various weeds in different regions of the world.

It was observed that when copper sprays were used against leaf diseases in India and East Africa, there appeared to be effects on the trees beyond those which cured the disease. The copper appeared to act as a tonic, and a great deal of work has been done on this during recent years.

Gillett[2] records how a severe leaf fall occurs in Kenya at certain periods of the year which is not accountable to any known cause except a possible loss of vitality. Bordeaux spraying not only controlled the leaf fall but markedly increased the yields, and this was attributed to a 'tonic effect'. The results obtained at the Scott Agricultural Laboratories gave conclusive proof, it is said, that such spraying is not only beneficial and economic in certain areas but essential for the successful cultivation of coffee. The results of experi-

ments were tabulated, and a note added to say that the sprays were applied with a power sprayer at the rate of one-half to one gallon per tree. Concentrated sprays were applied to other plots for four successive years with a fog sprayer, since water is a limiting factor on some estates.

Treatment—Power Spraying	*Average yield for 8 years cwt. per acre*
A. 1% Carbide Bordeaux each year in March	9·7
B. Ditto twice, March and June	9·4
C. ½% Carbide Bordeaux each year in March	8·3
D. Ditto twice, March and June	10·4
E. 1% Burgundy mixture, March	9·5
F. Control	4·8

Treatment—Fog Sprayer	*Average yield for 4 years cwt. per acre*
A. 4% Carbide Bordeaux at rate of 2–5 pint/tree each year in March	6·0
B. Ditto twice a year, March and June	9·9
C. Control	5·5

It would seem that two fog sprays are necessary to equal the benefit given by one conventional spraying in March. The average increase in yields was four-and-a-half hundredweight per acre, a very striking return. It was noticed that spasmodic flowerings were less likely to occur on the sprayed plots, the leaves were a darker green, and the ripening of the crop was improved. Trees that were sprayed did not show the same exhaustion when bearing a crop.

Perkins[3] states that not only did Bordeaux spraying on a larger scale consolidate a twenty-five per cent increase in yield on a Mount Elgon estate, but the crop ripened earlier with less exhaustion to the trees. He states that the treatment became one of the routine operations on the estate.

Jones[8] who reported on other trials, where no significant differences in leaf fall were noted when using Bordeaux, Burgundy and Perenox Sprays, stated that from the evidence available it seemed that the maximum benefit was derived from spraying when the rate of growth was at its peak.

Rayner[4 5 8] has reviewed the research work on tonic spraying from time to time and appeared to be not quite convinced that a tonic effect was in fact the cause of the increased yields. He pointed to the effect of non-copper sprays, which were very striking, and gave very strong evidence, he said, that copper sprays were acting through their fungicidal properties and not as a tonic as hitherto supposed, though the results did not suggest that there were better sprays for controlling leaf fall than the copper sprays in use.

It is obvious from the literature that there is still a lot to be learnt and a good deal of investigation to be made covering the varying regions and

environments where coffee is grown. The only definite guidance which can be given to coffee growers is that it is wise to spray with a copper fungicide when the trees are making new growth. This will not only help to prevent leaf disease, but will possibly have a tonic effect on the trees. At least it has been proved that leaf fall is prevented and higher yields are gained.

Rayner points out that a Burgundy mixture or a cuprous oxide spray are easier to handle than Carbide-Bordeaux. Though a bluestone mixture is visible on a tree for a long while, a cuprous oxide spray is easier to prepare and handle. He advises a two per cent concentration at one pint per tree using a fog Eclipse type sprayer. Burgundy mixture costs much more than either of the other two.

Carbide Bordeaux ...	2% mixture.
Ingredients ...	8 lb. copper sulphate.
	3 lb. calcium carbide.
	40 gall. water.
Cuprous Oxide ...	2% mixture.
Ingredients ...	42 oz. Cuprous oxide. Compound 50% copper.
	40 gall. water.
Blitox	2% mixture.
or	
Cuprokylt	10 lb. to 100 gall. water.
Perenox	7 lb. to 100 gall. water.

The effect of such spraying is said to increase the leaf-life by about three months, and this must be of the greatest importance to the health of the tree. A reduced concentration of the spray together with an increase in the rate of application gives much better coverage.

IRRIGATION

NEED FOR IRRIGATION WHEN RAINFALL IS SHORT

Irrigation as applied to coffee should be considered as a means whereby the subsoil, and not the surface soil, may be supplied with enough moisture. Coffee is an evergreen, and evergreen shrubs or trees not only require larger quantities of water during most months of the year, but they obtain their moisture chiefly from the subsoil in dry weather. This is the reason why Arabian coffee requires a high rainfall of seventy-five to eighty inches per annum to maintain optimum health and yield, and why a region with an erratic rainfall and long dry spells is not ideal. Irrigation is an artificial and by no means a perfect method of making up deficiencies; in fact, if it can be dispensed with, irrigation is best avoided.

If, therefore, a region is subject to dry spells and erratic rainfall, but otherwise has a good average annual rainfall, it may be that irrigation can be avoided by moisture-conservation methods. These comprise ridge terracing to provide a sluggish run-off and more time for soakage, mulches to reduce evaporation, shade and windbreaks to reduce transpiration, and the keeping of the soil in good texture so that water may be absorbed and percolate to the subsoil. Should these methods not suffice to prevent a deficit in the subsoil, then irrigation will be helpful if it is available.

The irrigation required in a coffee orchard, as opposed to the amount required by a crop being grown by the aid of irrigation in a semi-arid area, is the amount by which the rainfall has failed, and the dosage should be suffi-

cient to keep the whole root-range supplied, not merely to moisten the top few inches of soil. The shortage of rainfall is found by determining the mean annual and monthly rainfalls and measuring the shortages in the critical months. An orchardist should have a raingauge and keep careful records. It is only by comparing records that guidance is given as to when irrigation is needed.

For instance, it is necessary to take note of the rainfalls during successful preceding years, to discover the amounts which were required to bring the trees into full flower at the proper time, and the amounts which were sufficient to carry the good yields without undue exhaustion to the trees, and also the amounts which were enough in the succeeding years to recuperate the trees after harvest. Close observation and careful recording will discover the critical times when moisture is required, and also the amounts needed. It is at those critical times when preparations should be made to irrigate, should this become necessary.

If rain is falling but the rainfall is noticeably below average, it is not wise to wait until the top soil is dry, or a fine spell of weather intervenes. The spectacle of a planter irrigating during rain may amuse neighbours but not be as foolish as it seems. If, on account of an erratic season the rainfall is merely delayed, and falls too late after irrigation has been carried out, there is no reason to be alarmed or to think that an excess of moisture may do harm, provided the drainage is good. Too little is far more likely to do harm than too much during those predetermined and critical months.

Many factors influence the availability of moisture in soils, and the amounts required from natural or artificial sources to give sufficient to a crop: factors such as the type of soil and its absorptive or retentive qualities, the daily temperatures, the amount of sunshine or cloud, and whether the air is still or windy, to name a few. It is impossible for anyone to be exact unless a prolonged and scientific investigation has been carried out at some research station in his locality.

Irrigation and Mulch Experiment, Lyamungu.

Cwt. of Clean Coffee per Acre

Unshaded Arabian Coffee

Mulch per tree	*Irrigation Effective rainfall made up to*:				*Average yields*
Banana trash	*Nil*	*2 in. monthly*	*4 in. monthly*	*2 in. fortnightly*	
Nil	4·57	6·93	7·20	6·10	6·20
40 lb. end of long rains ...	7·24	8·89	8·44	8·39	8·24
80 lb. end of long rains ...	7·21	8·06	8·08	8·52	7·97
40 lb. at end of short and long rains ...	6·60	8·51	8·05	7·80	7·74
Average yields ...	6·40	8·09	7·94	7·70	—

The results published at Lyamungu in Tanganyika, for instance, might not be the same elsewhere, because less, or even more, irrigation might be found desirable, and the interaction of irrigation and mulching be found different. Planters must help themselves by observation and recording, and while a diary of their own lives might be considered a foible, a diary of the day-to-day happenings on a farm or a plantation is of extreme importance.

The tabulated results of the irrigation *cum* mulch experiment at Lyamungu show that either irrigation or mulching alone boosts up yields. The best returns were obtained when the rainfall during the drier months was made up to two inches and a forty-pound mulch was given at the end of the long rains.

Biennial bearing is brought about by influences other than the 'on' and 'off' years, when climatic influences are chiefly responsible for a difference in crop yields, because some selections of Arabian coffee may bear bumper crops in the 'off' season, and be correspondingly poorer during the following 'on' season on account of exhaustion. It has been stated in reference to Lyamungu, however, that soil moisture has been a limiting factor to a high level of annual cropping. Soil moisture at some time subsequent to flowering has not always been such as to allow the required level of nutrition to be maintained during the 'on' year to ripen the crop, and, at the same time, to produce wood ready to flower in the following season. Most of the irrigated plots, and the irrigation plus mulch treatments, tend to show that biennial bearing is curbed up to a point despite the higher yields. The degree or intensity of biennial bearing is much less than with coffee receiving mulch and no irrigation at all.

SOIL MOISTURE

There are several terms used in relation to soil moisture and these will be explained in brief. Firstly, 'field capacity' represents the amount of moisture for which the surface-tension of the moisture film round the particles of soil exceeds the force of gravity, and this varies with the soil texture. The 'minimum moisture content' is the amount beyond which plants obtain moisture with difficulty, and in order that a crop may not be injured, it is then desirable that water should be applied.[1] Deep-rooted orchard plants may be permitted to reduce the moisture content in the surface soil beyond this point, while moisture remains in sufficient quantity in the subsoil.

When plants begin to wilt and droop and do not recover during the night, then the 'wilting percentage' has been reached. This means that drying-out has proceeded too far and that injury has been done. The plants may recover when water is given, but the effects of the check will be shown in a shortened growth or a reduced yield. The 'readily available' moisture in the soil lies between field capacity and the minimum moisture content. It is this level which should be maintained, more particularly in the subsoil and deeper root range of orchard crops, and especially when they are evergreen.

MEASUREMENT OF IRRIGATION

Surface waste is the amount of water which runs away during rain or irrigation and does not soak in on account of the fine pores of a soil or the saturation of the top layers. A useful unit of measurement is the cu-sec, i.e., the volume of 1 cubic foot of water moving at a velocity of 1 lineal foot per

second. Measurements of furrow irrigation may be made conveniently at check gates where the cross-sectional areas of the water channel in square feet may be multiplied by the average velocity in feet per second to give the discharge or flow in cu-secs. A flow of 1 cu-sec continued for an hour would give 1 inch of water per acre if surface waste was disregarded and the water were spread evenly over the land.

Maintenance of Permanent Shade

The permanent shade trees should begin to give a light shade when they are three years old. During their early growth they may need a little attention such as the pruning of side branches to provide clean boles. The branches should not begin to spread out until they are well above the coffee, and the idea is to obtain a light canopy through which at least 50 per cent of the light can filter. Its value is to diffuse the light, and since the sun is on the move, the light and shade values as far as the leaves of the shaded crop are concerned are changing all the while. After three years the shade may grow too dense, and thereafter there must be regular shade-reducing cycles carried out on bright sunny days. It is not so easy to judge the amount of shade which should be left, when the weather is dull.

The object is to keep the shade trees alive and vigorous during the lifetime of the coffee, and as with coffee, it is not easy to fill vacancies and establish young trees in an old plantation on account of root competition, even by the use of pole cuttings. Rough pruning is equally unsuitable for shade trees as for coffee trees, and though many authorities speak of lopping shade trees, it is a task that must be carried out by a man skilled in axework. He should carry a saw, an axe and a heavy machete or chopping knife and it is essential that all these implements should be sharp. Green, sappy, or soft wood may be sliced off with a machete with a clean cut, but a saw is required for tough wood and thick branches.

In pruning off a heavy branch, the shade pruner should be taught to undercut it first, so that when it is sawn from above it does not tear a strip of bark away as it falls. No 'hat pegs' should be left, nor splintered peg-like stumps in which decay and disease may begin. An axe may be used for undercutting or for exceptionally heavy work, which, in fact, should seldom be necessary if the shade trees have been properly pruned from the start.

Heavy prunings should be carried off the land and used for firewood, or disposed of by burning or decay, and the ashes or decayed material afterwards taken to the compost yard. The smaller, soft, and green prunings, and as much of the leafage as possible, should be left and slashed into smaller pieces to decay *in situ* and add to the mulch. Though shade reduction may be done at any convenient time when labour is available, the best times to reduce shade should be after the coffee pruning, or before the long rains and the months of dull weather when the shade trees are not making new growth. At no time should the shade become too dense.

The density of shade will regulate cropping, and is a means to prevent overbearing in regions where temperatures are too high and overbearing is likely to occur. The denser the shade the less will the fruiting wood ripen and initiate flower buds, while a light shade will help to reduce the temperatures at ground level, permit the process of photosynthesis to continue, and give a regular and sufficient flowering in accordance with the strength of the trees.

The density of shade should be regulated at the time new growth is beginning in regions where the next crop is borne on the young wood.

Orchard Sanitation

If a coffee or a shade tree dies, it should be uprooted without delay and carried away to be burnt so that it does not infect surrounding trees with root diseases which may be encouraged by dead tissues. Coffee prunings should always be carried off the land and burnt to reduce the incidence of pests and diseases. Pests and diseases are treated fully in their appropriate chapters, but it will do no harm to reiterate that cherry coffee should not be left on the trees eventually to fall to the ground, even though there may be so little left on the bushes towards the end of harvest that it is hardly worth picking. It harbours bean-boring insects which are thus able to bridge the seasons and multiply when the next crop begins. A general clean-up should take place at pruning time shortly after harvest.

Buildings

Long before the first crop is due, proper facilities for pulping, fermenting, washing, drying and transporting coffee must be prepared, including cover for sun-dried coffee during showers of rain, well-built store sheds and so on. Most of these matters are discussed in the chapters on harvesting and curing, but the author has found that much expense can be saved by making the maximum use of local materials.

Take, for instance, the walls of store sheds and smaller buildings. There is no reason in frost-free regions why these should not be constructed of dried mud bricks provided they are built on good solid foundations topped with a damp-proof and a termite- (white ant) proof course of strong cement, with internal floors of concrete properly bound to this course. The bricks are laid without pointing so that they may be protected inside by a weak cement plaster, and outside by a strong rough-cast cement cover. If the window and door sills are made of a strong cement and slanted so that moisture cannot lie on them, the whole structure may be made to look as though it were built of kiln-made bricks.

Such a building will last as long as any other and be just as efficient provided the roof is hipped at both ends, and, if gutterings are not permitted, the eaves are carried out well beyond the walls so that the water from the roof falls into a drainage ditch surrounding the building. Now that corrugated cement-asbestos sheets are procurable, they form better material for a roof than corrugated iron. The roof framework may be made partly of sawn timber and partly of straight saplings and yet make a neat job. It is important to see that all the timber is hard and resistant to boring beetles. Open-sided and airy store sheds can be surrounded by a wall of tough expanded metal netting and thus have doors which may be locked.

For the reason of gaining even temperatures, for expediency, or an aesthetic taste, one is tempted to adopt thatched roofs. There may be thatching material handy or a local people skilled in thatching, but even so thatched roofs should never be used except for very temporary structures, and even these must be kept at a safe distance from other permanent buildings. The great danger is fire, and the fact that thatched roofs soon begin to harbour

insects such as wasps, hornets, wild bees, and vermin such as rats, bats and snakes.

The Labour Force

Unskilled labour may be provided from neighbouring villages or recruited by contract from afar, and housed on the estate. It is necessary to house them comfortably, treat them fairly as fellow human beings, see to their welfare in sickness and in health and pay them in accordance with their standing and the current local rates of pay. If the estate wins a good name, there is often no trouble in obtaining more labourers during the seasons when they are required.

Skilled labour and the clerical and supervisory staff may also come daily to work from neighbouring villages, though if there is land to spare they may be housed and encouraged to live on the estate.

The work should be arranged as much as possible so that there is no great fluctuation in the labour force, and mulching which suppresses weeds is very helpful in this respect. At harvest time the labour force may be strained to its limits and there is no one to spare for weeding and such-like tasks without doubling the labour force, a practice which is not easy when the people know they are to be engaged only for a short period. In some countries, however, it may be possible to engage women and children for picking coffee at lower rates of pay, and thus keep the higher paid and permanent staff on work that is more skilled. Fair treatment and a wise programme will hold staff who can be trained and become trusted, whereas the man who must constantly change his employees is at an extreme disadvantage. One cannot teach or guide a man how to keep his employees contented and happy and yet get the best out of them, for the power lies within himself, his attitude towards them and the amount of thought he gives to their welfare.

The Life of a Coffee Plantation

The astonishing thing is the slow rate at which a coffee tree pruned to the single-stem method reaches maturity. People talk of the first bumper crop of the young exuberant coffee trees as though this must be the biggest of their lives, and this takes place after a 'fly' crop, usually in the third or fourth year of an orchard's life. From then onwards, on account of periods of exhaustion and recuperation, followed by more bumper crops, the trees continue to bear crops that only gradually, and almost imperceptibly, increase in weight until, at the age of about fifteen years, recorded statistics prove that they are bearing on the average twice as much as they did when they were four and five years old.

An older tree is, therefore, of much greater value than a younger one, and if it is a single-stemmed tree it may, perhaps, bear as big, if not bigger crops than a tree pruned to the multiple-stem system, which, on account of the constant renewal of stems of the same size and kind, cannot be expected to yield more when once the maximum yield has been obtained. With the single-stem tree the strength is apparently gained in the ageing thickness of the trunk and branches, where more nutrients can be stored to bear larger crops, always provided the tree is healthy and being grown in a region wholly suited to coffee.

Whereas young Arabian trees four to five years old will bear at the rate of five to six hundredweight of clean coffee per acre, fifteen-year-old trees will bear at the rate of fourteen to fifteen hundredweight per acre, having borne an extra hundredweight of coffee per acre for every year of their lives. Why then does a coffee-growing area yield on the average only three-and-a-half to eight hundredweight of coffee per acre?

The answer is given (1) in the gaps that occur in an old plantation where coffee has been somewhat carelessly treated; (2) the fact that seed has not been sown from selected trees; and (3) because part of the land should never have been planted on account of poor patches of soil, for the reason that the planter has endeavoured to plant too large an area over which he can neither exercise sufficient supervision, nor give the land and the coffee the proper treatment and care. For these reasons the average yields of coffee orchards throughout the world are ridiculously low.

Who knows how long coffee trees will live and prosper and give increasing yields in a region where the environment is ideal? Single-stemmed trees and orchards are known which are thirty, fifty, and eighty years old and still as good as ever. Trees of robusta coffee on the Sese Islands in Uganda still bearing good crops are said to be more than a hundred years old. On the other hand a plantation of Arabian coffee in a hot country of low rainfall will cease to give economic returns in a matter of six years and thereafter die of disease and die-back.

The aim of research is to increase the production of a unit area. This has been shown to be possible. It seems, indeed, that with proper care a coffee plantation may be made to yield a steady fifteen hundredweight of clean coffee per acre per annum from its fifteenth year, having gradually increased production from about six hundredweight in its fourth year. Surely the aim of the owner of a coffee plantation should be the same. It should not be frustrated by a lack of sufficient initial capital, which prevents an owner providing the full requirements indicated in this book.

At the price of coffee ruling when these words were written (£600 per ton average), the gross return from a 250-acre coffee plantation at 15 hundredweight per acre per year would be £112,500 per annum. Even at £60 per ton, a price to which Arabian coffee is unlikely to fall for many years to come, the gross return would be £11,250 per annum, surely well worth the investment of £15,000 capital.

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Chapter XII

THE HARVESTING AND PREPARATION OF COFFEE

The Ripening of Arabian Coffee

The green glistening berries of Arabian coffee gradually swell to full size while every preparation is being made to deal with the crop, not forgetting to bring the normal work on the estate right up to date and if possible a little in advance. Most of the labour must soon concentrate on the harvest, and it is amazing how weeds grow apace and how quickly a plantation looks neglected when all the many tasks are suspended for a while. One must not forget to have sacks and sewing twine in readiness and to clean out or prepare dry storage of sufficient space.

If the young trees are healthy and bearing a good crop, in their third or fourth year, the yield may average about 3–5 cwt. of clean coffee per acre. The out-turn of clean dry coffee from ripe 'cherry' is round about 16–18 per cent, so the yield of ripe 'cherry' will be in the neighbourhood of 1 ton 10 cwt. per acre in that first crop year. In other words about 375 tons of 'cherry' or 60–65 tons of cured coffee from 250 acres.

What is so alarming to the planter is, that within a few days after the berries have turned yellow, the whole plantation is bearing red-ripe fruit which must be picked without delay. It all seems to ripen at once, and if labour is short, or preparations are delayed, it really is frightening. Actually, from the time the berries begin to turn red, a week or ten days may pass while they reach their full red colour, and another week or a fortnight may pass while they are gradually turning off colour and becoming over-ripe. From the moment most of the berries turn red, there are about two or three good weeks in which to harvest the main crop and, if all sorts of helpers are encouraged to work, and, perhaps, to work overtime, the crop may be comfortably and safely gathered without loss.

One must naturally abide by what other planters in the neighbourhood are doing in the matter of pay, and concerning tasks if piecework is done. Piece-work, especially for overtime, helps to get in the crop, though the system is not good from the point of view of damage to the trees and evenness of picking. In the haste to accomplish a task, a worker will tear at the branches and strip the berries ruthlessly; he will pick green berries along with the ripe ones, and he will endeavour to pick from the crowded branches, and leave scantily fruiting ones alone. No matter what system is used, a trusted headman must be in charge of the pickers, another at the factory, and yet another at the drying grounds.

Staggering Harvest

On big plantations or in areas where labour is short it would be an advantage if ripening could be staggered. The author has seen no records that this has ever been done deliberately, but there are indications in several references that it might be possible. Plantation treatments such as irrigation or the

reduction of shade might bring some blocks of coffee into full harvest slightly in advance of others. The irrigation of some blocks before the start of the rains would normally cause the trees to flower earlier, and irrigation when the fruit was ripening might hasten this process.

The system of pruning can do a lot to alter the time and size of the harvest. In some districts of Kenya, the multiple-stem system has changed the main crop from August–December to May, June and July,[13] so that one would then only need to have both the single and multiple systems used side by side to stagger the harvest from May until December. In regions where the trees flushed into flower only once during each year the crops from either might not be spread so much.

It is difficult to prevent biennial or even triennial bearing of coffee, especially in short rainfall areas where good crops exhaust the trees, and they take a year or two to recuperate according to the amount of die-back present and the degree of exhaustion. Older trees get out of rhythm, and some bear their best crops in off seasons, while the other trees are recuperating from the previous season's harvest. Pruning encourages the trees of some blocks to bear their best crops at a different season, for when once the impetus to biennial bearing is given by a good crop, the effect is carried on for a number of years as will be shown in the experimental recordings of the Lyamungu Station.[19]

A harder pruning of single-stemmed trees at the time when the flower buds are about to become differentiated, will throw them into growth instead of flower, thus depressing the crop in that year in favour of the next year when there should be a plentiful supply of young wood on which an extensive flowering will take place. Any method of reducing a crop in the 'on' year and deferring it until the next should throw trees so treated out of rhythm with the rest.

Tonic spraying with copper solutions, mentioned in the chapter on maintenance, is said to bring a crop in earlier, doubtless because leafage is thereby saved to supply more carbohydrates to the ripening berries.[14]

On an estate planted with any strain of coffee grown from seed, there will be trees which vary in the time of ripening of their fruit, and this may be recorded over a period of several years. It should be possible by a careful selection of mother trees, and the subsequent testing of the progeny, to arrive at strains which would ripen at different times insofar as the peak period of harvesting is concerned. Varieties differ up to a point, and this is a matter for local test if it is desired to stagger harvest by planting more than one variety. Ferwerda studied the time taken between flowering and ripening of different coffee varieties in Java[5] and found a difference of only five days between 'robusta' coffees, twelve days between 'Arabian-Liberian' hybrids and robustas, and thirty-nine days with 'robusta excelsa' hybrids. He stated that the length of ripening character appears to be acquired exclusively through the female parent in all hybrids.

In regard to *Coffea canephora*, i.e., 'robusta' coffees in Uganda, Thomas records how the main crop of the erect form var. *canephora* ripens in the dry season of January and February, and the main crops of the spreading form var. *nganda* ripen in November and December. He states that the early ripening of the spreading form is the secret of their vigour in a normal year, for the fruit is removed by December and the trees have two months to grow before a new crop is set at the end of February or in March, whereas the

erect forms are loaded with berries until January and February and thus have little chance to make new growth before the rains induce flowering and the setting of a new crop.

McClelland[12] gives an interesting table showing the ripening season and the percentage of crop harvested each month for the respective species, varieties and forms.

CROPPING SEASON AND HARVEST PERCENTAGES

PORTO RICO

Species and variety or strain	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*
Arabian.												
Mocha ...	5	37	52	6	—	—	—	—	—	—	—	—
Bourbon ...	15	31	37	14	3	—	—	—	—	—	—	—
Murta ...	6	40	38	11	5	—	—	—	—	—	—	—
P.R. Las Vegas	14	32	24	27	3	—	—	—	—	—	—	—
Erecta ...	3	39	40	13	5	—	—	—	—	—	—	—
Padang ...	1	31	41	22	5	—	—	—	—	—	—	—
San Ramon ...	2	12	28	21	26	11	—	—	—	—	—	—
Maragogipe ...	—	7	34	37	18	4	—	—	—	—	—	—
Columnaris ...	—	5	27	40	22	6	—	—	—	—	—	—
Robusta.												
1. ...	—	—	1	13	29	44	10	3	—	—	—	—
2. ...	—	—	1	7	19	46	18	9	—	—	—	—
Quillou ...	—	—	1	15	27	45	9	2	1	—	—	—
Congensis ...	—	—	3	13	20	43	13	8	—	—	—	—
Liberian.												
dewevrei ...	—	—	2	6	26	28	20	9	4	1	1	3
liberica ...	2	—	—	1	9	41	26	16	4	1	—	—
Excelsa ...	—	—	—	—	—	5	5	28	22	18	15	7

There is a considerable difference in the ripening season of the species, while there is less between the varieties and forms of a species. *Coffea dewevrei* differs from the others in its prolonged season, though it more closely resembles the *C. liberica* group than it does *C. excelsa.* This is yet another indication that it may be a hybrid or a form of Liberian coffee rather than being closely allied to excelsa coffee as Chevalier states.

HARVESTING ARABIAN COFFEE

The harvest should start as soon as the berries turn red. They must be red-ripe like cherries, hence the term 'cherry' coffee, and they must not be the least green. Coffee-pulping machines are most efficient when they are dealing with red-ripe juicy 'cherry' coffee of even ripeness, but when unripe or over-ripe berries are mixed with the ripe ones then no coffee pulper can be adjusted to do its work properly. Too much pulp then passes through with the parchment, beans are crushed and nipped, and some may pass through and be wasted with the pulp. The factory foreman should report at once if unripe berry is being picked.

The pickers must be trained to strip the berry from each tree swiftly but gently without injuring the tree. It is not a difficult task.

THE BERRY AND ITS CONTENTS

In a normal berry there are two seeds each flat on one side and rounded on the other; the flat sides are in juxtaposition. These are the so-called coffee 'beans' of commerce. They are shaped somewhat like cowrie shells, since the rounded edges are folded inwards forming creases down the middle of the flat sides. They are separately enclosed in thin membranes called 'silverskins', and in parchment-like shells also shaped with creases down the middle of the flat sides.

The two seeds and their coverings are enclosed in a thin mucilaginous substance which is sweet to the taste, and immediately surrounding this is the somewhat thick skin of the fruit. If a ripe oval fruit is squeezed at one end with the fingers, the pressure bursts open the other end and the two seeds fly out. The principle of the pulping machine included in the wet process of preparing coffee, is to force the seeds to fly out through apertures, while the skins of the fruit are pulled beyond and thus separated. Since more and more berries are being fed into the machine by gravity it will be understood that the operation is successfully accomplished only if the seeds (or coffee beans) are held in their slippery mucilaginous covering, and if the skins of the fruits are soft and ripe enough to burst open. Should any under-ripe and hard unyielding fruits enter the machine, or over-ripe berries that have partly dried, then a blockage tends to take place. The hard or partly-dried fruits are imperfectly pulped, the beans crushed, and a great deal of pulp passes through the apertures along with the pulped parchment.

Pulped coffee in its parchment covering is called wet or dry 'parchment' coffee. Coffee that has had its coverings removed is called 'hulled' or 'cured' coffee, and curing cannot be done until the parchment coffee has been fermented and fully dried or the 'cherry' itself dried sufficiently to allow of it being hulled. In both cases the bean itself within the parchment or 'cherry' husk, must be tested before the product can be rated as dry enough to treat. If coffee is pulped and washed it is said to be prepared by the wet method, but if the whole 'cherry' is dried and then hulled, the process is called a dry one.

Among the flat-sided beans are some which are oval and round. These are called peaberries, and they are found in smaller fruits which have set only one seed. Within the skin of the fruit it is often possible to see the second seed as a rudimentary speck of tissue, because, on account of some accident it was not fertilized at birth, or did not mature because it did not receive enough

nutrients. The peaberries are eventually sold separately. They fetch a good price in countries that do not use mechanical roasting, because they will roll during roasting and are therefore roasted evenly.

Then there are beans called 'elephants', and these are again accidents, or monstrosities, and are sometimes two seeds literally rolled into one. They are uneven in shape and sometimes bursting through their parchment coverings, the embryos rolled together in a chaotic manner. The same phenomenon may be seen in some orange pips, which are bigger than usual and burst their seed coats. Like the orange pips, and the seeds of other citrus fruits, these abnormal seeds of coffee will sometimes produce more than one seedling when they are sown in a nursery bed, a character referred to as polyembryony. It is, however, unwise to use them for propagation.

When the peaberries and 'elephants' have been separated from among the flat-sided and normal beans, there are broken beans and immature pieces which still cannot be allowed among first-class graded coffee. These bits and pieces are also separated from the mass and become known as Triage. A great deal of immature bean is found among light coffee 'cherry' or parchment, and this is the result of (*a*) exhaustion on account of over-bearing and die-back, or (*b*) a severe attack of *Antestia* sucking bugs. It is possible to have parchment of mature size and yet containing nothing except a shrivelled speck, too small to be counted as Triage.

Crop Variation

The prepared or cured coffee bean varies in size, percentage and quality for several reasons. The flat-sided beans are usually graded into A, B, and C grades—bold, medium and small, though the trade may alter grading slightly from time to time to suit market requirements, or consumer's preference and the country where the coffee is to be sold. This is done by readjusting the sizes and percentages within the grades.

But all this is mechanical and not a variation at origin. The first crop from young trees usually presents a large percentage of bold coffee, after which the amount of bold coffee and its quality depend on the varying strength of the tree, on climatic and seasonal influences, on locality and soil and so on. In any one season the quality and size of the coffee will differ on various estates in any one region because of the treatments given, the aspect of a slope on which the coffee is planted, or the strain and variety grown. The quality and size may vary on any one estate from trees growing on a hillside or in a valley, or where there is any variation in the soil.

Along with such variations and quality, the out-turn may vary according to the weight and size of the bean in relation to the fruit, the out-turn being the percentage of cured bean to the weight of fresh cherry. Beans may be large or small and plump, or large or small and lacking weight. Coffee tends to deteriorate towards the end of a picking season, and there is variation within the range of values for the cherry-parchment ratio for the different pickings from the same tree. There is a wide variation in different seasons for the same tree and the seasonal variation is much greater than that between trees.[23]

Mean Values of the percentage of hulling loss obtained by the formula:

$$\frac{(\text{Bulk parchment} - \text{bulk clean})}{\text{bulk parchment}} \times 100 = \text{per cent hulling loss.}$$

KENYA ARABIAN COFFEE

	1936–37	1937–38	1938–39
Mean hulling loss%	21·050	19·190	20·301
Number of trees	71	157	68

N.B.—The accepted estate value for the hulling loss is 20 per cent.

Comparison of out-turn data for two trees (A — B) in four seasons, is shown as mean Sample Ratios and mean Percentage Hulling Loss.

Trees	*1935–36*		*1936–37*		*1937–38*		*1938–39*	
	A.	*B.*	*A.*	*B.*	*A.*	*B.*	*A.*	*B.*
No. of samples	3	4	5	3	8	9	3	4
Cherry/parchment ratio ...	4·9	4·7	5·0	5·5	5·3	5·6	5·0	6·1
Cherry/clean ratio ...	6·4	6·3	6·3	7·6	6·7	7·1	6·3	7·3
Hulling loss%	23·9	26·3	21·4	25·6	20·7	20·3	21·5	17·0

FREQUENCY TABLE (200 BEAN SAMPLES)
WEIGHT OF BEAN IN GRAMMES

Mid-value	*A tree of var. bourbon*				*A tree of cv. 'Kent's'*			
	Pickings				*Pickings*			
	2	*3*	*4*	*5*	*2*	*3*	*4*	*5*
·075	—	—	—	—	—	—	—	1
·085	1	—	—	—	1	—	—	1
·095	—	—	1	1	7	1	1	3
·105	5	5	4	3	22	4	5	7
·115	5	13	5	8	22	17	7	15
·125	16	25	19	31	39	28	11	14
·135	26	14	12	31	32	23	24	14
·145	45	28	41	36	27	31	29	30
·155	29	34	28	34	21	35	42	29
·165	39	48	53	18	15	21	42	33
·175	11	16	15	18	5	16	29	12
·185	10	6	14	7	5	13	5	17
·195	3	4	3	2	2	2	4	7
·205	2	1	3	2	1	4	—	8
215	1	2	—	3	—	1	—	4
·225	2	2	—	1	—	2	1	3
·235	1	1	—	—	—	—	—	—
·245	2	—	1	4	—	—	—	—
·255	1	—	—	1	—	—	—	1
·265	—	—	—	—	—	1	—	—
·275	—	—	—	—	—	1	—	—
·285	—	1	1	—	—	—	—	1
·295	—	—	—	—	—	—	—	—
·305	—	—	—	—	—	—	—	—
·315	—	—	—	—	—	—	—	—
·325	—	—	—	—	—	—	—	—
·335	—	—	—	—	—	—	—	—
·345	1	—	—	—	—	—	—	—
Corrected estimates of means ...	0·155	0·153	0·155	0·150	0·136	0·150	0·154	0·156

When a large number of individual values were examined in East Africa it was found that the mean hulling loss was 19·76. There were indications that 'quality' is to a large extent a varietal character, but environmental factors are important and one of these may be shade.

In Tanganyika after 1936 a great deal of research was done to discover what number of beans in a sample would be sufficient to characterize a tree, the average proportional size and weight of beans at picking cycles and so on. The following tables and data from Lyamungu's report for 1936[19] are interesting.

FREQUENCY TABLE (TOTAL CROP)

LENGTH OF BEAN IN MM.

Mid-value mm.	*A tree of var. bourbon*					*A tree of cv. 'Kent's'*			
	Pickings					*Pickings*			
	2	*3*	*4*	*5*	*6*	*2*	*3*	*4*	*5*
5·3	—	—	—	—	—	—	1	—	—
5·5	—	—	—	—	—	—	—	1	—
5·7	—	—	—	—	—	—	—	—	—
5·9	—	—	—	—	—	1	—	1	2
6·1	—	—	—	—	—	1	2	3	3
6·3	—	—	—	—	1	4	—	1	—
6·5	—	—	—	—	—	5	2	3	—
6·7	—	—	—	—	—	6	1	6	1
6·9	5	—	—	2	1	14	9	8	4
7·1	4	1	1	2	5	24	30	14	8
7·3	2	1	1	—	3	56	29	16	14
7·5	1	—	—	1	6	48	13	20	7
7·7	5	—	—	1	9	33	10	25	5
7·9	19	4	1	5	16	73	75	44	27
8·1	25	7	13	24	29	73	124	73	41
8·3	11	9	9	21	35	101	83	99	26
8·5	14	7	8	7	44	75	44	103	16
8·7	35	5	8	5	60	61	32	80	11
8·9	134	32	50	78	69	99	153	148	52
9·1	162	62	82	147	110	63	171	152	62
9·3	60	39	36	86	86	68	82	182	37
9·5	65	19	40	48	77	33	46	125	21
9·7	120	12	16	41	83	16	21	54	13
9·9	277	86	125	145	93	43	86	88	27
10·1	175	90	137	150	69	13	50	56	37
10·3	49	49	52	60	57	15	21	37	8
10·5	34	13	16	25	25	11	4	19	4
10·7	50	5	13	21	14	6	6	5	5
10·9	80	32	38	47	20	3	9	7	5
11·1	17	12	25	23	10	3	6	—	3
11·3	9	2	10	11	3	3	2	3	—
11·5	3	1	1	2	5	—	—	1	1
11·7	3	2	—	1	4	—	3	—	—
11·9	4	5	2	2	2	—	1	—	2
12·1	—	3	—	2	1	—	—	—	1
Corrected estimate of mean ...	9·523	9·798	9·803	9·687	9·496	8·461	8·845	8·980	8·935

The range of bean length from any one tree according to the tables is 5·3–12·1 mm. The bourbon has a longer bean with the second picking pre-

dominating, but the 'Kent's' had its peak at the fourth picking. The difference in duration of crop appeared to be accounted for by the nature of the flowerings.

The width of the beans was measured by shaking them through sieves with circular holes as used in curing works, and the sizes of the holes were as follows:

9B.	6·875 mm.	The A's of commerce.
8	6·750 „	
7	6·625 „	
6A.	6·500 „	
5	6·375 „	
4	6·250 „	
3A.	6·125 „	
3	6·000 „	with a uniform difference of ·125 mm.

FREQULNCY TABLE (TOTAL CROP)

WIDTH OF BEANS

ACCORDING TO SIEVE MEASUREMENT

Sieves	*Bourbon tree, pickings*					*'Kent's' tree, pickings*			
	2	*3*	*4*	*5*	*6*	*2*	*3*	*4*	*5*
9B.	479	146	299	429	344	89	251	300	142
8	230	77	96	119	130	73	106	172	46
7	110	45	40	84	87	59	103	154	23
6A	145	73	67	85	112	90	103	150	34
5	93	60	64	93	118	108	100	189	53
4	27	10	18	29	19	35	39	51	16
3A	86	34	32	47	50	107	103	68	37
3	45	24	19	27	34	75	44	53	25
Remainder	196	61	80	161	133	318	284	248	81
Total ...	1,411	530	715	1,074	997	954	1,133	1,385	457

The bean of the bourbon tree proved larger in width with 36 per cent of 9B grade against 20 per cent for the 'Kent's' coffee.

Grouping for boldness was achieved by passing the beans through 'pea-berry' screens, the sizes of which were:

Large	...	more than 4·198 mm.
Medium	...	„ „ 4·127 „
Small	...	„ „ 3·921 „
Remainder	...	less than 3·921 „

FREQUENCY TABLE (TOTAL CROP)

BOLDNESS

ACCORDING TO SCREEN MEASUREMENT

Grade	*Bourbon tree, pickings*					*'Kent's' tree, pickings*			
	2	*3*	*4*	*5*	*6*	*2*	*3*	*4*	*5*
Large ...	169	61	74	148	120	186	274	202	105
Medium ...	42	15	25	37	49	76	74	54	12
Small ...	133	46	51	89	78	69	101	63	37
Remainder	1,067	408	565	800	750	623	684	1,066	303
Total ...	1,411	530	715	1,074	997	954	1,133	1,385	457

The second picking is still the peak for the bourbon tree. 'Kent's' proved superior for this character with 19 per cent of bold beans as against 12 per cent for the bourbon. It must be emphasized that this work was all preliminary to get an idea of the ranges and ratios in accordance with pickings. The results from single trees cannot give the true characteristics of the varieties in question.

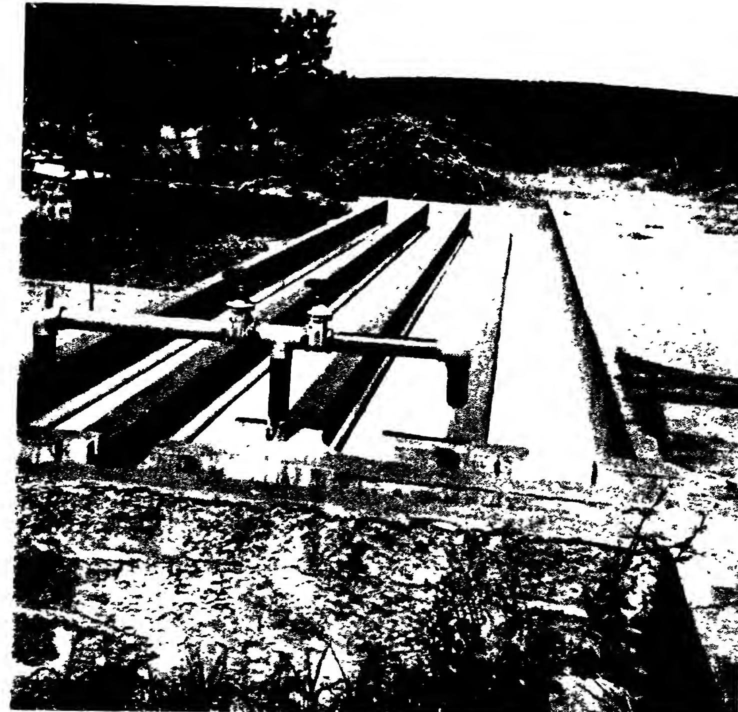
A number of other measurements were taken from coffee growing on various estates in the Northern Province of Tanganyika, and the work justified itself by proving that trees exist which bear beans significantly larger and heavier than their neighbours. A tree selected for yield which averaged at a rate of 29·4 cwt. an acre for three years, was also outstandingly good in the characteristics of its beans. Higher-altitude estates generally produced better quality in regard to most measurements. It was impossible to conclude from the data that any variety was superior, because the differences may have been due to environment. By working out the correlation coefficient on samples of beans from individual trees it was shown that:

1. Heavy yielders do not necessarily give light beans.
2. Heavy yielders do not necessarily give small beans, in fact there is a tendency for good yielders to give heavier and larger beans.
3. Long beans are not necessarily flat beans.
4. Long beans are not necessarily narrow beans.
5. Long beans are generally heavy beans.
6. Wide beans may have a positive correlation with weight.
7. Flat beans are usually lighter beans.
8. Width and boldness are seldom correlated.

Further attention was given to bean weight in 1937 when it became known that a random sample of all the pickings must be taken to characterize a tree, and the number of beans in a random sample must be more than 350. The following frequency table given for another tree shows how the weight of beans may fall off as harvest proceeds.

By courtesy of A. R. Melville, Esq.

(b) Final washing and grading channel



By courtesy of A. R. Melville, Esq.

(a) Pregrading channels (rubber hoses have been removed)

PLATE XXXVIII

By courtesy of the Royal Institute for the Tropics

(*a*) Drying coffee on barbecue, Idjen plateau, East Java

(*b*) The use of a washing channel in Kenya. The parchment coffee is pushed and agitated against the flow with wooden paddles

By courtesy of the Kenya Information Office

PLATE XXXIX

FREQUENCY TABLE FOR BEAN WEIGHT

WEIGHT IN GRAMMES

Weight	*Pickings* 2	3	4	5	6	7	8	*Total*
0·075	—	—	—	—	—	7	14	21
0·085	—	—	—	3	14	9	20	46
0·095	—	—	—	4	12	22	30	68
0·105	—	1	2	17	33	57	69	179
0·115	2	4	3	40	49	77	83	258
0·125	—	3	4	55	80	108	120	370
0·135	2	8	6	84	126	138	175	539
0·145	5	10	30	125	171	173	186	700
0·155	9	16	38	174	168	179	171	755
0·165	18	27	42	208	171	144	109	719
0·175	32	32	42	161	102	132	84	585
0·185	36	46	36	115	52	75	44	404
0·195	35	50	21	39	39	43	25	252
0·205	43	22	9	10	14	8	5	111
0·215	26	16	5	4	4	—	1	56
0·225	15	5	2	1	1	—	1	25
0·235	7	1	—	2	2	—	—	12
0·245	5	—	—	2	—	—	—	7
0,255	—	—	—	—	1	1	2	4
0·265	—	—	—	—	1	1	1	3
0·275	—	—	—	—	—	—	—	—
0·285	—	—	—	1	—	—	—	1
0·295	—	—	—	—	—	—	1	1
0 305	—	—	—	1	1	—	—	2
0·315	1	—	—	—	1	—	—	2
0·325	—	—	—	—	—	—	—	—
0 335	—	—	—	—	—	—	—	—
0·345	—	—	—	—	—	—	—	—
0·355	—	1	—	—	—	—	—	1
0·365	—	1	—	—	—	—	—	1
Totals ...	236	243	240	1,046	1,042	1,174	1,141	5,122
Means ...	·193	·182	·169	·159	·152	·149	·143	·155

A study of the specific gravity of beans was begun because of consistent trade opinions that compactness is connected with quality.[1 19] A wide variation is to be found between random samples from different trees, the specific gravity ranging in tested samples from 1·15 up to 1·40. It would seem that this quality is connected more with the roasting qualities than with 'cup' quality. A tree with very heavy and large beans with a specific gravity of only 1·15 over two years test, received a good report for cup quality but a poor one for roast.

The actual size of the cured bean, unlike its evenness, does not have much effect on quality. Some of the finest quality Kenya coffee has a small, but even and well-made bean.[23] The well-known mocha coffee gives a small-sized bean.

Moisture-absorbing Properties of Dried Parchment and Cherry

Marked hygroscopy has been demonstrated in coffee.[24] The process of drying is never continuous, for some of the moisture dried off during the day is reabsorbed during the night, especially if the atmosphere is humid. The property appears to be characteristic of all coffees, and it is the humidity of the air and these reabsorptive properties which have probably been responsible for the poor colour of Arabian beans produced in Uganda in the past.

Flow of Coffee by the Wet Method of Preparation

SITING A PULPERY

Since ample water supply is very necessary, and since a great bulk of heavy cherry must be transported there for treatment, the pulpery should be sited at the lowest and the most central point on the estate wherever the water happens to exist. From the act of picking through all the processes of its preparation, the product must flow in the most convenient and economic manner from high level to low level, in such a way that at the end of each phase the bulk and weight of material to be transported away, or uphill again, has been reduced to the minimum. Nothing can be cheaper than a gravity flow by the aid of water that has not been pumped, and this can often be arranged to the inflow level of the factory by furrow and flume.

The cherry is either brought by lorry or head-load to the pulpery in sacks, or it flows by flume from the nearest point in the field to the pickers, and enters the factory via a large hopper, whence it passes into a tank filled with water where the heavy cherry sinks and is separated from any light cherry that may be present. This is done by siphoning the cherry to the pulper from the lower part of the tank, and the flow of water into the tank being greater than that through the siphon, the light cherry floats away through a high level escape where it is collected nearby on a drainage table—still at high level—or is delivered at once to a separate and smaller pulping machine for immediate treatment. Small stones and pebbles are trapped at the bottom of the reception tank so that they are not siphoned with the cherry to the pulper. The reception tanks must be cleaned out at the end of each day's harvest, or at stated intervals if the pulpery is run non-stop. (*See* Fig. 30.)

Red-ripe coffee cherry should not be mixed with under- or over-ripe fruit and never contaminated with earth. Moreover there should be as little delay as possible in pulping the 'cherry' after it has been picked, because the juicy fruit soon begins to ferment. Cherry coffee must all be pulped within twelve to twenty-four hours, because if it is kept in bulk it soon gets overheated. If cherry coffee must be kept longer than this it should be placed in tanks of cold water, or in sacks placed in a running stream, and even then it would not be wise to keep it unpulped for longer than another day. The finished product is so easily tainted by rotting pulp. Unclean water or stagnant water from swamps may also give the ultimate product a taint which is detected by the tasters when the coffee is marketed. Any over-ripe coffee that has lost its juiciness towards the end of harvest should be soaked in cold water for a day before it is pulped.

Needless to say, any coffee that is not first class, either because of some

By courtesy of the Tanganyika Public Relations Dept

(*a*) Picking coffee cherry in a native co-operative field, Kilimanjaro Mt

(*b*) Bukoba native grower hulling his dry cherry coffee by dragging a rock over it The cherry is laid on an outcrop of rock, and it is in such situations that much of the coffee is dried

Photo by author

PLATE XI

By courtesy of the Kenya Information Office

(*a*) An Arabian coffee estate in Kenya unshaded because of high altitude. Note Napier grass in foreground being grown for mulching purposes

(*b*) An Arabian coffee estate in Kenya, unshaded because of high altitude

By courtesy of the Kenya Information Office

PLATE XII

mishap, or because it is end of crop, over-ripe, or from a diseased or pest-infested field, should be picked, prepared and bagged separately.

PULPING AND SEPARATING

Both pulper and separator machines should be fixed at a medium level with ample space surrounding them. The cherry arrives with the water and fills into the hopper of the pulper where its flow is regulated. No matter what its make, the pulper must be carefully adjusted, so that it is not too tight or some of the beans may be nipped, nor too loose, or pulp may pass out with the beans, and beans pass to waste with the cherry skins. One can only adjust a pulper to take coffee of even ripeness and size, and if coffee is being picked under-ripe it should be reported to the field. It is easy to see when too much pulp is coming through with the beans, but good coffee is often thrown out behind with the waste skins and forgotten. The percentage of waste can be considerable because the skins hide the beans, so it is most important to examine the waste pulp as it is discharged from the back of the coffee pulpers. When only one pulper is used it is possible to examine the pulp at any convenient place in the waste channel, but if a battery of pulpers is used then samples should be taken from the back of each pulper in turn.

The pulped bean will always have a percentage of cherry skins and smaller-sized imperfectly pulped cherries which often contain peaberry. The bean must, therefore, flow into a separator; either a shaking sieve or better still a rotary sieve. The larger pieces of pulp and the imperfectly pulped cherries are taken to a smaller pulper which is more closely adjusted and often called a re-passer. The bean obtained from the re-passer may well be formed of a high percentage of peaberry and it is best to make it flow into a separate fermenting tank. The light cherries floated off from the initial reception tank may be taken to another machine and pulped separately, or stored and treated at the end of the day's run. Bean from light cherry should again be fermented separately.

The peeled skins which fall at the back of the pulper should pass into a concrete channel graded so that they may flow away to a drainage place where they can be heaped for ultimate use in compost making.

The flow of coffee is assisted by an excellent supply of clean water. This can be made to carry away the empty pulp. Water flowing in appropriate channels also takes the separated beans to the re-passer, and other machines, and thence to the fermenting tanks.

PRE-WASHING AND SEPARATING FLOATERS

Between the pulper and the fermenting tanks there should be space for the concrete channels in which the parchment coffee is to flow. It is here that some planters like to arrange for a preliminary washing and perhaps a rough grading, as the coffee flows to the tanks, in which case the channel should be widened for the purpose.

There are two methods, both somewhat similar, for separating the floaters from the sound bean on its way to the tanks. In the first the channel forks in the shape of the letter Y with a sluice gate fitted on one side. At the entrance to the open arm of the fork a sunken ledge is placed to turn away the heavy coffee to the other channel, while the light coffee flows over the ledge to its

proper tank. The other arm of the fork has the sluice gate dropped into the stream to allow the heavy bean to pass underneath it, but to turn the floating coffee to the other channel. The parchment floaters may be arranged to flow and join the light coffee obtained from the floating cherry, and be fermented together in one tank.

The second method is called a 'whizzer'. The coffee flows swiftly down an incline into a circular basin in such a way that it is swirled round, the heavy coffee passing under a sluice gate and the floaters over a sunken ledge into a separate channel as before. The difference is that the whizzer, if properly constructed, separates most of the bits of coffee pulp from the heavy coffee as well, because these rise to the surface as the beans eddy round and they flow away with the floaters.

The conducting channels are arranged so that additional water supplies may be turned on by tap at convenient points, to help the flow of the bean, with a series of sluice gates and take-offs to direct the coffee into any tank. It is convenient to have hose attachments for use in the washing channels.

Though it is unnecessary, a preliminary washing before fermentation is a refinement practised by many coffee planters striving to produce the finest coffee possible. It is said that they are afraid of over-fermentation if the bean is not washed in this manner beforehand, and a chance is given for a rough grading of the best and boldest coffee and to get rid of bits of pulp or floaters before the good coffee flows into its fermenting tank. Some may consider the act wasteful of labour. It also tends to wash away some of the mucilaginous matter containing sugars on which a good ferment depends, and information included in this book under the heading of 'Onion Taint' should be carefully considered.

FERMENTING TANKS

The pulped parchment should flow into fermenting tanks at low level. These tanks should be arranged in series so that empty ones are available for use while other tanks are being cleared. The coffee may be made to flow to any tank by the manipulation of sluice gates and branch channels.

Fermenting tanks should be of a size and number to cope with several days' maximum crop, allowing for at least two grades of parchment to be kept separate, i.e., that from the good cherry, and that from the light cherry which may be mixed with the floats from the pulped coffee. It is usually convenient to build rectangular tanks of concrete, but all corners should be rounded, otherwise fermented coffee beans may stick in the corners. Each tank should be constructed so that the water may be retained or drained away.

Installations and the dimensions of fermenting tanks may be decided in conference with firms who equip coffee factories. Much depends on the size of the plantation and on the power supply available. A planter knows his acreage and therefore his maximum yields, and he should always err on the generous side and prepare for a maximum crop rather than an average yield.

With the acreage and yields known, a supplying firm can advise on the installation required. Moreover, by this time the planter has, if he is wise, gained experience of other plantations and their methods of working.

Fermenting tanks are normally 3 ft. deep at the inlet end and 3 ft. 6 in. deep at the outlet end, allowing for an average depth of pulped coffee of 2 ft. 6 in. The number of tanks, or tankage space required, depends on the

rate of fermentation. Coffee may be wholly fermented within twelve hours, or it may take eighty hours depending on temperatures and high altitudes. There is a small saving of labour and a great saving in capital expenditure if coffee can be fermented in twelve hours, since fewer tanks will suffice.

If the duration is only twelve hours, the coffee pulped today may be washed and the tanks emptied in time for tomorrow's pulping. One might therefore have one large tank for the good parchment in bulk, a smaller tank for the floaters, and a third for the coffee pulped by the re-passer machine.

There must be empty tankage space available for each day's coffee, or for every twelve hours' or twenty-four hours' pulping. If the rate of fermentation is slow, then tankage space must be duplicated or replicated as the case may be.

As pulping proceeds, the water outlet from a tank is closed until the tank is filled with its complement of parchment. This deters the ferment in the bottom layers progressing beyond the subsequent ones. When a tank is filled, wooden paddles may be used to stir the coffee, and any floaters and foreign matter can be skimmed off the water before it is drained away. It is then wise to cover the coffee with hessian or old sacks, but these should be clean and washed after each day's use.

FERMENTATION

The pulped bean remains in a tank until fermentation is complete, and the time of fermentation depends on seasonal variations and temperatures. It is best if the tanks are covered by roofing to protect the coffee from cold showers of rain which might interfere with the ferment. After a while the time taken to ferment the coffee becomes generally known, provided there are no seasonal variations, but it is always wise to test the coffee and not to rely upon rule-of-thumb methods. The parchment should be washed as soon as it is ready.

In Kenya it is believed that the coffee is improved by giving it a wash in the tanks every morning, irrespective of whether fermentation has been completed or not. Fermentation at high altitudes may take more than two days, and one would have thought that such pre-washes might delay fermentation by washing away the organisms and the sugars on which fermentation depends. Coffee parchment should not be fermented in a tank full of water. It should lie in bulk as a sticky mass with the water drained away.

When first pulped, the seeds (beans) of coffee are soft and heavy and tightly packed within their immediate parchment-like seed-coats and the flesh of the beans is a dull porcelain white. They are slippery and sticky with mucilage on the outside, and before the parchment is dried it is best to remove this mucilage by a fermentation and washing process. The fermentation of coffee should do nothing else. It is not done to alter its composition or flavour as happens when cacao beans are fermented, and the process is carried on for just as long as it takes for the mucilage to liquefy and dissolve. The greatest care must be taken to see that coffee is not over-fermented, and it must be washed and drained of moisture as soon as fermentation has reached the appropriate stage.

The slippery, slimy covering to the bean is no longer present when fermentation is complete. If the parchment is squeezed between the fingers the shell-like coverings grate together amidst a sloppy mess and it is then ready to be washed. Should an attempt be made to dry coffee without fermentation and

washing then the process of drying takes much longer. The seeds agglomerate together as they dry, with the mucilaginous pulp becoming tacky, holding moisture and attracting dirt. A further and dangerous ferment might take place during the drying if the parchment coffee has not been properly fermented and washed beforehand.

In the coffee trade one hears of raw coffee being designated by the tasters as 'over-fermented' or 'under-fermented'. These are trade terms given to what one might call a taint, or a recognized taste, and they are often applied loosely insofar as the origin of that taint or taste is concerned, because proof of the actual cause is often lacking. It is possible to over-ferment. The peak period of fermentation is passed while the organisms and yeasts are working on the sugars in the sticky mucilage, so when the parchment is ready to wash, the beneficial fermentation is complete. It can, in fact, proceed no further, though the parchment is now lying in a sloppy fluid in which chemical changes have taken place. A sourish, vinegary odour begins, and if the coffee is permitted to lie unwashed too long, it is likely to pick up taint and thus be said to be 'over-fermented'.

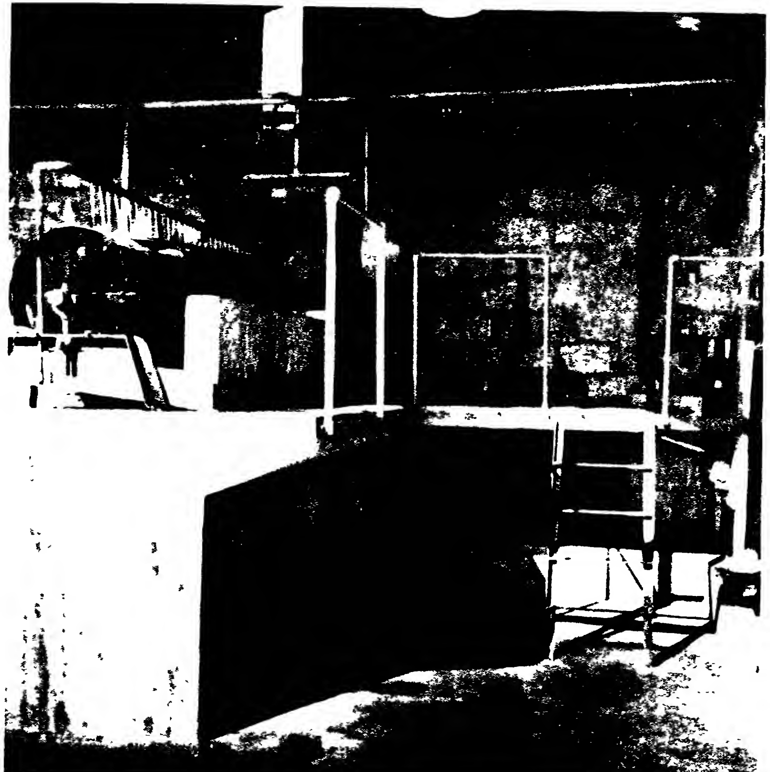
That coffee cannot truly be under-fermented is proved by the fact that machines are in use to rub off and remove the sticky covering to render fermentation unnecessary, purely to economize in labour.

Supposing, however, in ordinary estate practice the coffee is washed before all the mucilage matter is removed. The parchment then tends to become dirty. It is still somewhat sticky and it is liable to pick up a taint, or a slightly different taste derived from the juices of the pulp as it continues to ferment and ultimately dries on the parchment covering, giving a liquor that is recognized as 'under-fermented'.

All this points to the advisability of strict cleanliness in the pulping factory, to a careful supervision of the fermenting process, and to the thorough washing of the coffee at the correct time. Every means should be taken to see that unripe, over-ripe or light coffee cherry is pulped separately from the good, sound ripe cherry. Fruit skins which pass through the pulper should also be separated so that they do not flow into the fermenting tanks with the parchment.

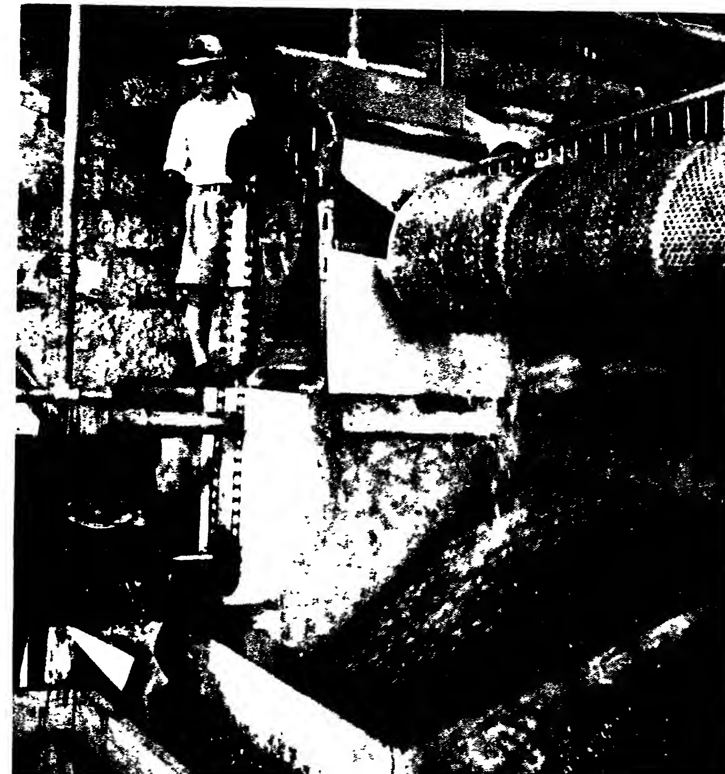
Much can be done during the pulping process to separate the poor coffee from the good in an automatic and economical manner. Not only does this avoid uneven ferments and possible taints but it saves costs in separating when the coffee is cured. A tale is told (and the author has seen the sample) of a consignment of 'light' parchment coffee which was sent to London for curing in the old days when *Antestia* bug was such a menace in Uganda. Except for its lightness the parchment looked all right, and it was tipped into the hopper of the hulling machinery. To the astonishment of the operatives nothing came out at the delivery end, for the parchment was indeed empty. This illustrates two things. Firstly that it is possible to separate light from heavy parchment, and secondly that empty parchment should never have been shipped home for treatment. It should have been burnt as useless, or worked into a compost heap where the natural heating would have destroyed any pests there happened to be in the empty material.

Fermenting parchment to rid it of its mucilaginous covering is not complicated. It is easy to tell when fermentation is complete, but the time may vary in accordance with a seasonal variation in atmospheric temperatures.



By courtesy of the Kenya Information Office

(*a*) Access to operator platform and switchgear

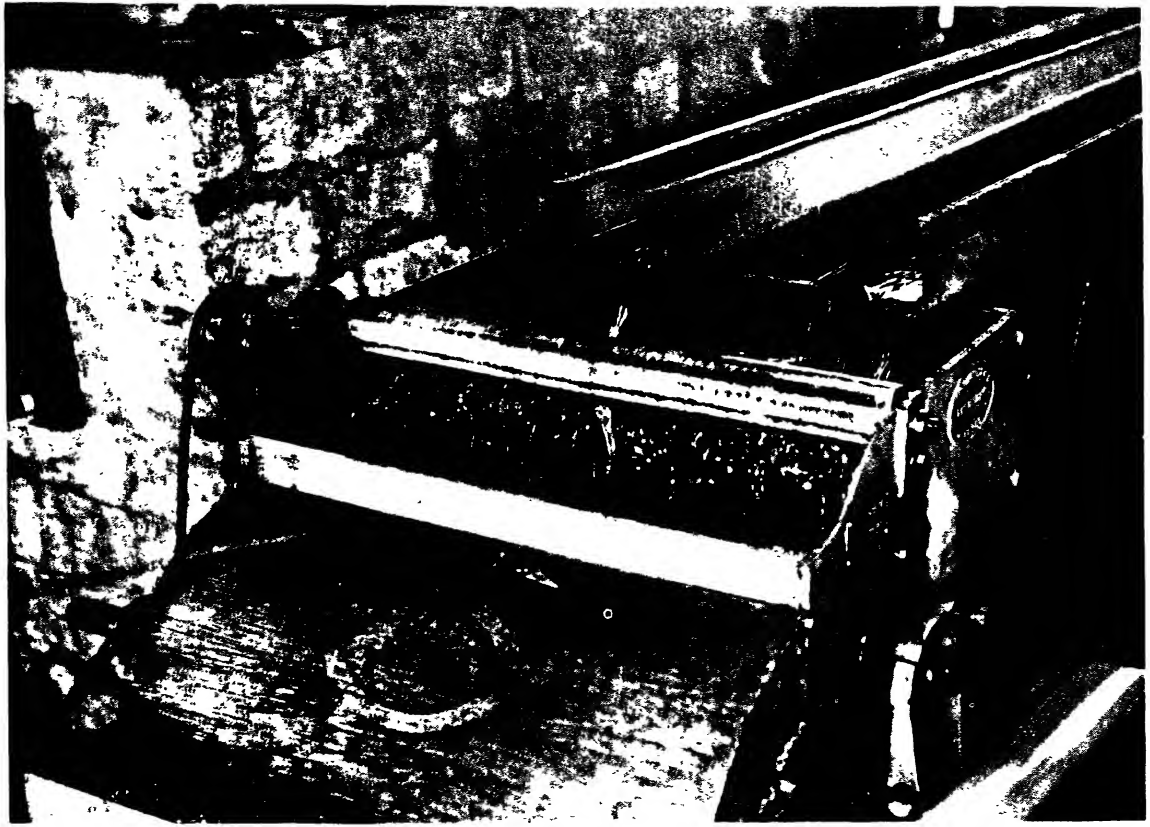


By courtesy of the Kenya Information Office

(*b*) General view of pulper installation

A pulper installation in Kenya

PLATE XLII



By courtesy of the Kenya Information Office

It is necessary that a copious supply of water should flow into the pulping machine with the ripe coffee cherry

PLATE XLIII

HASTENING FERMENTATION

One of the most important factors in the production of good coffee is the speed with which preparation is carried out and the time which elapses between the picking of the fruit and its ultimate drying down to a moisture content of from 10 to 12 per cent, at which it is safe to store under proper conditions. The changes taking place while the coffee is wet are mostly deteriorative, and in most cases deterioration is accelerated by high temperature, hence a rapid fermentation is not always wise.

The above facts suggested that means might be found to hasten fermentation by enzymes or chemical means. Tests are reported[8] on the use of 0·2 per cent pectic enzyme produced from moulds, based on the weight of the pulped coffee beans, and added experimentally to accelerate mucilage digestion. Together with a little warming, it succeeded in completely digesting the mucilage in less than one hour, compared with an average of thirty-six hours for spontaneous fermentation. By the use of 0·025 per cent of the enzyme, the mucilage could be digested in five to ten hours depending on the temperature.

Other reports propound that 'the unique purpose of fermentation is in the "solubilization" of pectins'. The necessary enzymes[21] are present in the pulp of the coffee cherry or are supplied by moulds or bacteria which develop swiftly in the fermenting tanks. The organisms raise the temperature in the tanks and speed the reaction.

The protopectin in the presence of the enzyme protopectinase is hydrolyzed into pectine. The pectine by demethylation and a partial or complete carbolation is transformed into galacturonic acid and methanol. The resulting insoluble pectic acid is swiftly transformed into galacturonic acid and all the end products are soluble in water.

The presence of at least two enzymes, pectinase and pectase, is necessary for these reactions, the second needing the calcium ion as a co-ferment. It is stated as possible that the formation of tetragalacturonic acid takes place first, this being broken down by a different enzyme pectolase.

The secondary process in a good fermentation must be confined to the production of ethanol and lactic acid which does not cause harm to the bean. The temperature is a little higher than the surrounding air and the pH drops from 6·8 or 6·7 to a point between 4·2 and 4·5 when the end point is reached. In practice this point is determined by testing the beans and discovering that they are ready for washing.

Lime has been introduced to precipitate the pectins, so that the formation of an insoluble pectate renders the mucilage unable to ferment, and the coffee can be dried without washing. Since the calcium pectate has a very weak adherence to the grain it can be eliminated mechanically with water if a sufficient supply is available.

It is argued that the lime process tried experimentally in districts where water was scarce, produced coffee indistinguishable from that produced in the orthodox manner. No claim is made to improve the coffee, but from a sanitary standpoint the elimination of fermentation and washing may be welcome.

The authors[10 21] report higher values for quality, and talk about top quality, but the pulped and enzyme-treated coffee is generally compared favourably

with the hard Brazilian coffee and not with the better qualities of mild coffees prepared in an orthodox manner.

Inquiries in Costa Rica have discovered no advantage in applying yeasts to hasten the fermentation process of first-class coffee artificially. Moreover, the yeasts used are by no means cheap. It was found, however, that cherry which is insufficiently ripe or partially dried through over-ripeness could be treated with advantage. The method is to pass the cherry through a machine which bruises the outer skin. The cherry is then placed in a tank and treated with yeast for a determined period of time, after which it can be passed through the pulper and fermenting process in the normal way. The resulting coffee beans are found to be indistinguishable in appearance, weight and cupping qualities from the first-class coffee. They are thus upgrading their lower grades in Costa Rica and the advantage in price may be more than the cost of the process.

On a plantation in Salvador where the fermenting tanks are rather deep, the coffee is heated to hasten fermentation. An air compressor is used to pass air into the coffee through perforated pipes. As air is compressed so does the temperature rise, and this is sufficient to bring the temperature up to 30°C.

Except for a small saving in labour and a possible capital expenditure on replicate tankage space, there does not seem much object in hastening a ferment provided a deterioration in quality is not taking place, and if the ferment is proceeding in the normal manner. From the beginning of harvest to the end, when once the first batch of fermented coffee is ready to wash, the preparation process is continuous and economical. It can be compared to the mass production assembly lines of a modern motor-manufacturing industry.

WASHING AND DRAINING PULPED COFFEE

The best arrangement, if the contour of the ground permits, is to have the washing channel so placed that it surrounds the tanks at the lowest level. The tanks may then be emptied as required through sluice gates straight into the washing channel. A channel is, of course, inclined at a gentle gradient, and the drainage should be at the lowest point. It is time-wasting and labour-absorbing if the coffee has to be lifted out of the tanks and deposited in the washing channel by hand.

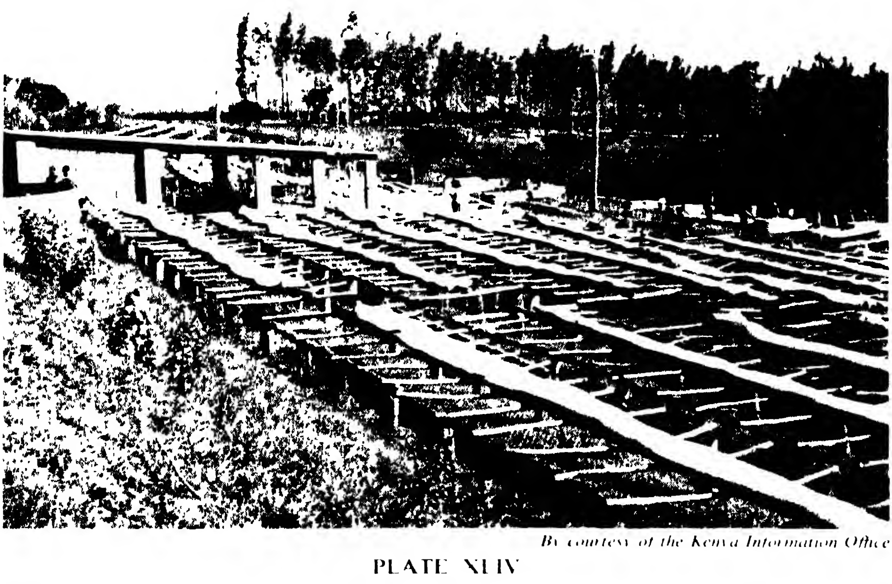
Immediately the parchment coffee has fermented and become sloppy it should be thoroughly washed without delay with clean water. It is first washed in its tank and then finished off in a washing channel against a gentle flow of water until it is clean. This should not take long, and during the process the smaller and lighter parchment tends to flow to the end of the channel while the heavier and bolder parchment comes to rest at a higher level. In this way can the parchment be roughly graded in a preliminary fashion into two or more grades while wet, and thus save a certain amount of work during the curing of it afterwards, provided thenceforward it is dried and treated separately.

A washing channel in Kenya may be four feet wide and 100 ft. long, with outlets at 50, 75 and 100 ft. The fall is 3 per cent over the first 50 ft. and 1 per cent over the remainder. Water is fed by a 3-in. water main, and blocking boards are placed at 50 and 75 ft. Final washing takes place in the first 50 ft. section, after which the water can be turned full on for grading. Skins and lights are collected at the open end on trays. When grading is completed the

By courtesy of the Kenya Information Office

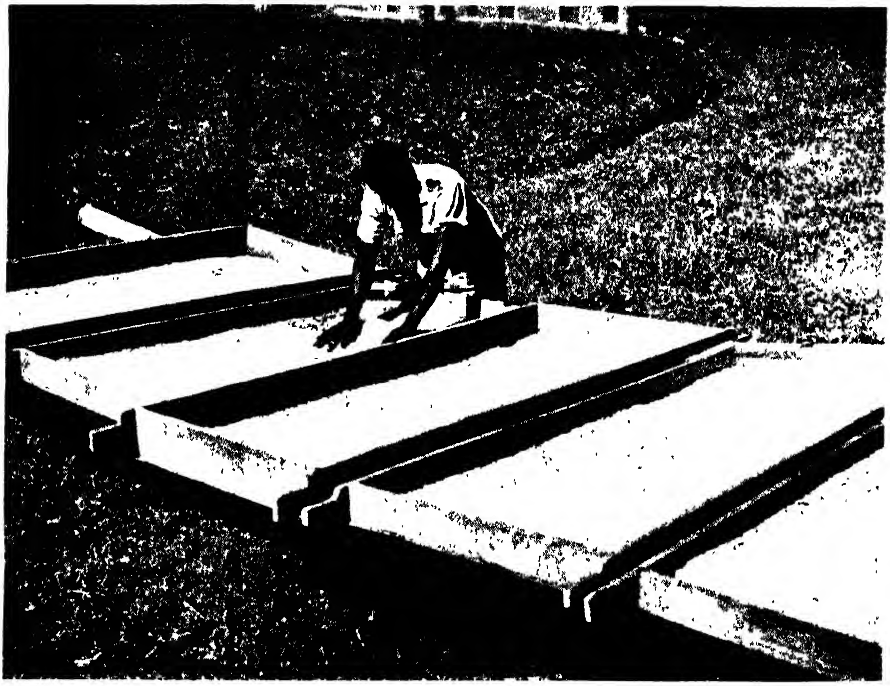
(*a*) Parchment coffee being sun-dried on an estate in Kenya

(*b*) A Kenya planter's coffee drying on wire staging and bundled in hessian for the night.



By courtesy of the Kenya Information Office

PLATE XLIV



By courtesy of Kenya Information Office

(*a*) Coffee Parchment in drying trays, Native Co-operative Society, Kenya

(*b*) Parchment coffee from Native Co-operative growers, Kilimanjaro mountain, being bulked at the Moshi coffee curing works

By courtesy of the Tanganyika Public Relations Dept

PLATE XIV

other two grades are washed out by lateral outlets on to trays or draining platforms large enough to take all the coffee from the first and second sections of the channel.[11] After the coffee has been drained it is carried to the drying grounds.

MECHANICAL WASHING AND DRAINING

There are mechanical washing machines both vertical and horizontal. The vertical cylindrical tank which has a central vertical revolving shaft to which agitators are attached, is the one, perhaps, most favoured. It has to be charged, and recharged of course, but clean water may flow into it so that floaters are separated while the heavier coffee is undergoing the process.

Centrifugal machines are catalogued for eliminating the excess moisture from wet parchment coffee, but these are expensive to use; they have to be charged and recharged, and the operation is sometimes imperfect on account of the peculiar shape and nature of parchment coffee. It may be considered cheaper to use a mechanical dryer with a larger capacity and leave the coffee in it a little longer.

PREVENTION OF THEFT

When clean coffee is worth several hundred pounds a ton it must be treated like gold. None of it must be lost through carelessness, none must be lost through theft. A planter's life during harvest is spent wandering in a circle from the field to the factory and drying ground, varying the times so that he may visit one or the other unexpectedly, watchful for those who may be giving a warning of his approach. The last task of the day is to place all the coffee under lock and key. Concrete fermenting tanks may have tough expanded metal covers padlocked to staples sunk into the concrete, but it is better if the tanks are contained in a part of the roofed-in pulpery where doors can be locked at night. Expanded metal mesh is an ideal material to use to enclose an open-sided coffee pulpery.

Store doors should always be kept locked, and half-dry coffee placed under cover where it can be safely locked inside. That is, of course, unless the people in the neighbourhood are entirely honest, in which case such actions might put ideas into their heads. Even so, theft is encouraged by laxity and may lead to a considerable loss of coffee. Planters have been known to buy coffee from smallholders, or to prepare coffee for them, which has emanated from their own estates.

DRYING PARCHMENT COFFEE

Parchment coffee is either sun-dried or dried in a flow of hot air. Rotary drying quickens the process but the temperatures and the time of drying must be watched to get each batch even, and neither under- nor over-dried. Some planters use both methods, and run the rotary dryer during the peak of the harvest or when the weather is dull. Sun-drying is usually the cheapest method because, of course, the heat of the sun is free.

Sun-drying is carried out in different ways. Trays about three feet wide by six feet long made of timber and wire mesh are used on many estates. These may have handles at each end so that two men can carry them in and out of cover, placing them in the sunshine on runners off the ground, and stacking

them one above the other under cover at night. On the other hand arrangements may be made to cover them out-of-doors at night, or during sudden showers, with tarpaulins or corrugated iron sheeting. Sometimes the trays are arranged on runners in tiers so that they may slide from both sides under a central roof.

The wet parchment coffee may also be placed on permanent three-feet-wide stagings of wire mesh covered with loose strips of strong hessian, which may be grasped at the corners and carried under cover, or have loose rainproof covers that can be put over them. Many of the larger estates use barbecues of cement with a lean-to roof at one side under which the coffee may be moved into shelter at night, or in wet weather.

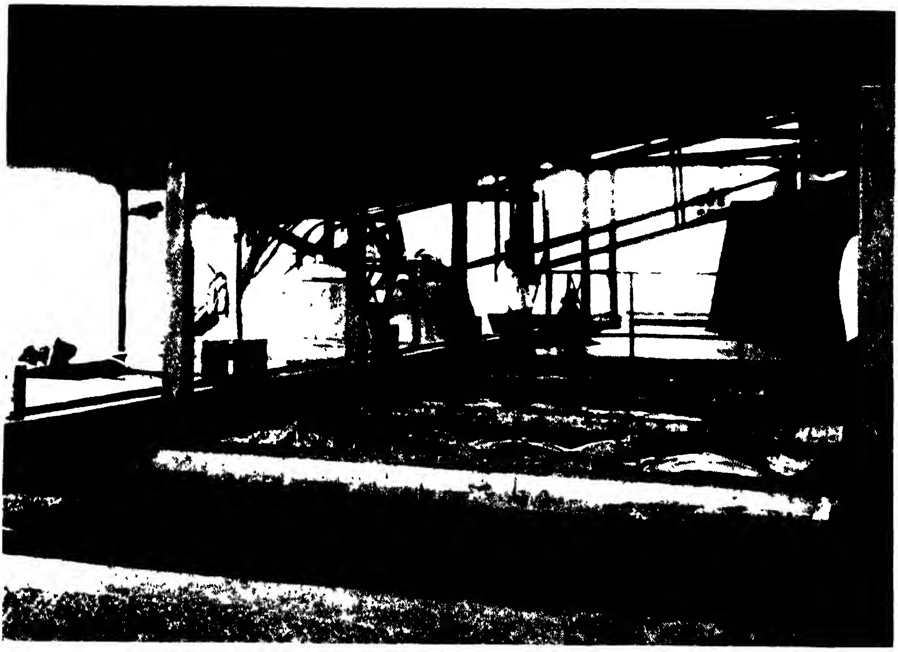
If the coffee is sun-dried it is convenient and economical to have the drying trays or barbecues near to the pulpery. This is not always possible because, to obtain the advantages of gravity flow and water supplies, the pulpery and the tanks are often sited on the lower slopes of a valley where mists hang about at night. It is better to have the drying enclosure situated on high ground, where the air is dry and breezy and sunshine is plentiful. Sun-drying should take from eight to ten days. The parchment should always be protected from showers of rain and from heavy dews at night. The colour of the ultimate bean depends largely on quick and thorough drying.

As it dries the bean changes colour to a dull and then a brighter bluish-green. It shrinks within the parchment shell and the silverskin loosens. A few seeds may be rubbed so that the parchment and silverskin break away, and the beans are tested by biting them. If they are hard and brittle and break with a snap, then the beans may be considered dry. A planter soon learns to tell whether coffee beans are dry by their colour, and by testing them with his thumbnail. When the parchment is dry it may be kept in dry storage without harm, either bagged or in bulk to await hulling.

Barbecues are used in regions where the rains cease during harvest. Light transient showers that merely wet the outside of the top layer of parchment are disregarded, because the following sunshine will soon evaporate the moisture and carry the drying process onward. It must be remembered, however, that coffee beans and dried coffee fruits are freely hygroscopic, and if they are re-wetted and absorb moisture during the drying process, considerable loss in colour and quality will result. The dried coffee bean will then sometimes have a spotty appearance.

The floors of barbecues should be of smooth cement and free from cracks. They should be kept scrupulously clean and not be used for drying other products from which taints may be derived. The drying coffee must be carefully treated and on no account should anyone wearing boots walk over it. If the parchment is broken and removed before the bean is dry, the cured bean may be white, and is then useless.

No matter which method of sun-drying is used, the parchment coffee must be kept turned so that it dries evenly and quickly in the strong sunshine. It is laid at first about one inch thick until the parchment begins to loosen, and coffee of the same batch may then be deepened in the trays, to no more than one and a half inches. The parchment coffee should dry in about eight days. It is false economy to lay it too thickly, and it will be seen that a number of trays and considerable space will be required. Provision for drying must always be adequate. If the crop comes in quickly and in quantity it may swamp the drying space if arrangements are inadequate, in which case it



By courtesy of the Royal Institute for the Tropics, Amsterdam

(*a*) Fermenting tanks, Kalisat estate, Idjen Plateau, East Java

(*b*) Washing coffee, east coast, Sumatra

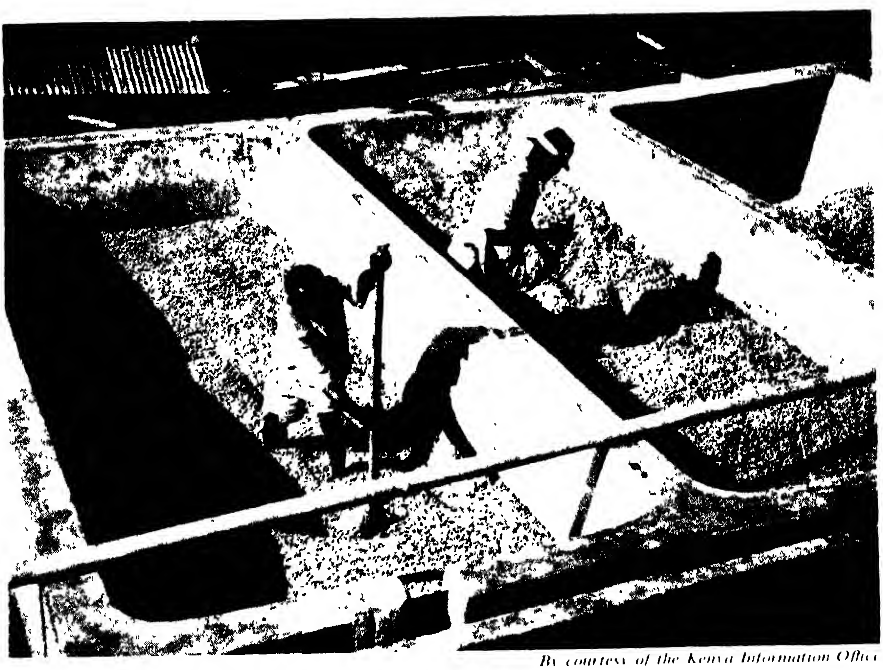
By courtesy of the Royal Institute for the Tropics, Amsterdam

PLATE XLVI

By courtesy of the Kenya Information Office

(*a*) Tipping cherry coffee into the reception tank at the pulpery

(*b*) While fermenting, the parchment coffee is turned daily. Kenya Colony



By courtesy of the Kenya Information Office

PLATE XLVII

would be piled up too thickly and take much longer to dry. Such a shortage of drying space becomes accumulative and dangerous.

The author has seen instances where planters have been forced to store half-dry parchment for weeks in cribs, and in bulk in store sheds, so that the coffee heated, became musty, and its quality and liquor utterly ruined. Such coffee loses colour and must be sold at something less than half-price, a disastrous end to several years of hard work.

In Central America when planters are faced with a heavy harvest it is quite a common practice to half-dry and store coffee parchment in such a manner. It is partially dried to what they call the *punto negro* (black point) or what in English parlance may be said to be the 'safe point', but this is possible without harmful effects only in countries where the weather turns dry at harvest time and the atmosphere is not very humid. It is a dangerous practice and one to be avoided.

Machine drying is imperative on large estates or for large co-operative enterprises, and rotary dryers of several kinds are the best for the sake of evenness. On smaller estates it is useful to have mechanical drying available during the peak harvest, or during spells of dull or wet weather. Mechanical dryers are available in different sizes and generally repay the outlay.

Some authorities state that mechanical drying may start at 85 to 90° C. and that these temperatures can safely be used for the first few hours, after which they should be lowered and remain even at from 75 to 80° C. for the remainder of the operation, in which case wet coffee may be dried in 20 to 24 hours instead of 30 to 36 hours. It is usually considered that a starting temperature of 80 to 85° C. is quite high enough, and that the temperatures should be lowered to 75° C. after six hours and so remain to the end. Air temperatures are deceptive and the coffee is seldom subjected to the temperatures indicated by the thermometers which are normally placed in the hot-air duct just before the air enters the dryer. The coffee being dried never approaches the temperatures of the air indicated at that point.

Planters vary in their methods and use of these machines. Some sun-dry for a few days and then complete the drying in a dryer, in which case a starting temperature as high as 85° C. should never be applied. A finishing temperature of 65° C. is recommended.

Others use a mechanical dryer for a while after sun-drying, and dry off for one day in the sun afterwards to complete the process. Still others use the dryer from start to finish.

Immediately after drying, the parchment coffee should be allowed to cool down before it is bagged or stored in bulk, and before it is hulled. It should not be heaped up in too great a bulk to cool, and is best moved or agitated. Some planters use cold air in the dryer and let it turn for a while before emptying out the coffee.

Dryers of various makes have facilities for drawing samples for testing. Over-drying means wastage. The usual loss in weight from drained to dried coffee is 40 per cent.

Dried parchment coffee may be bagged or stored in bulk to await hulling in dry storage, but it should not be kept too long in warm humid climates. Bagged coffee should not be in direct contact with a concrete floor and it should be stored on a wooden floor, preferably a few inches above the ground. It is not wise to store parchment coffee in bulk in cement or steel silos. It is much safer if it is in contact with wood.

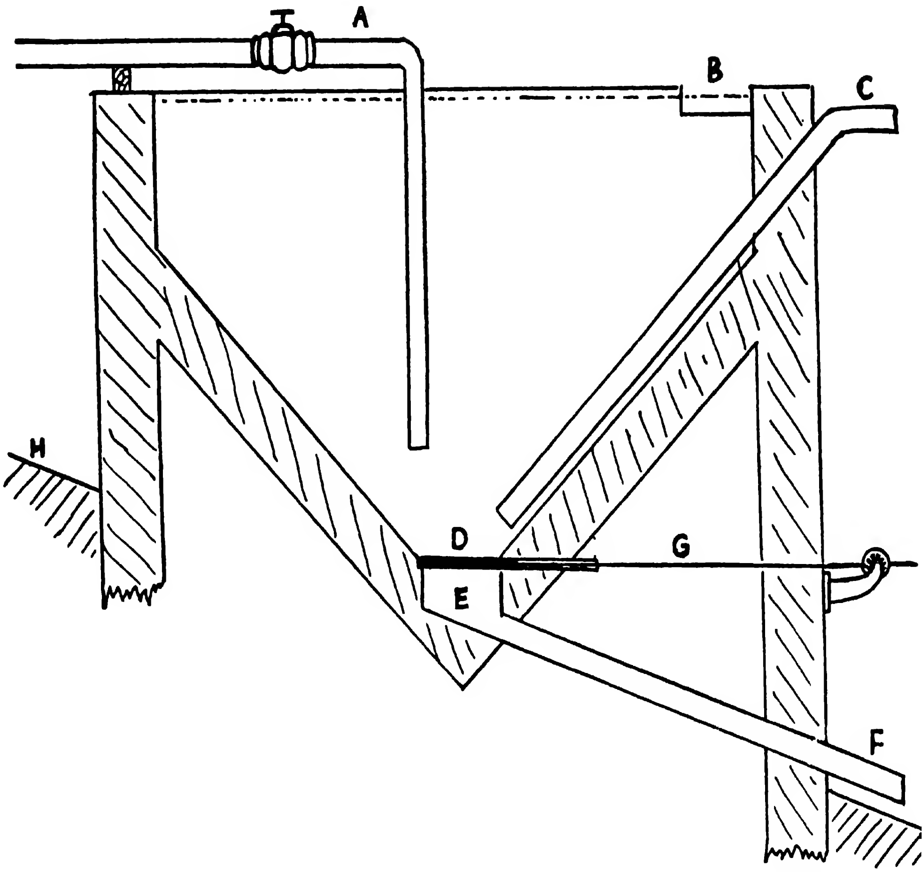


Fig. 30.—Concrete Reception Tank and Siphon Feed. A—Water supply. B—Outlet for floating cherry. C—Siphon outlet for heavy cherry to pulper. D—Gate over trap. E—Trap. F—Outlet for stones and mud. G—Gate rod. H—Slope of land.

Preservation of Machinery and Equipment

Farmers are proverbially careless with their equipment. They will buy an expensive machine and then leave it somewhere in the open to get rusty and overgrown with weeds until it is wanted again in season. Planters, in general, are a little better, but while visiting many properties the author has seldom seen a factory that might be called spick and span. Pipes are allowed to rust, concrete to chip, crack and corrode, machines are never repainted, brasswork never cleaned and repairs often improvisory. A factory, whether it be large or small, should be cleaned up every day, and in the off season the machinery, metalwork, and timber require overhaul, repair and repainting. A pin-point of rust on the outside of a corrugated-iron roof means, in all probability, that a wide scale of rust has peeled off on the underside where moisture has been condensing, and it is then too late to preserve the iron with paint.

Considerable corrosion and wear of cement plaster surfaces in fermenting tanks and washing channels take place on account of the acids which are evolved. Apart from the expense of replastering, it is difficult to clean the

rough surfaces resulting from corrosion and these are apt to retain undesirable odours. In Kenya success has attended trials with a paint consisting of two separate substances known as (*a*) Wintol 1. Primer and (*b*) Wintol cream finishing paint, manufactured by Messrs. H. Windsor & Co. Ltd., of London.

The paint is manufactured for the express purpose of protecting a variety of surfaces, including cement, plaster, and metal, from the effects of acids, and it is said to possess a high degree of scratch resistance. The manufacturers guarantee that the paint is innocuous in every way, and from experience gained at the Kenya Coffee Experiment Station[10] the protective paint is strongly recommended. The light colour of the paint assists inspection for cleanliness.

The Kenya Authorities recommend that only new plaster which has thoroughly set and been cleaned should be treated. One coat of primer and two of finishing paint should be applied in cool and dry weather on dry surfaces, allowing the first coat to dry before another is applied. The bottom and the lower sides of fermenting tanks and washing channels are the most important parts to protect, together with the drainage plates and effluent outlets. It is suggested that a single following coat of finishing paint might well be used in preparation for each subsequent coffee season. There was no evidence whatsoever that taints were given to the coffee after severe tests.

Brazilian or 'Hard Coffee'

As will be seen in the chapter on Brazilian coffee production, many Brazilian coffee planters have been slow to learn modern methods of production. The greater proportion of the Brazilian coffee crop is Arabian coffee, yet, in general, it is not called a mild coffee. The trees are usually grown from seeds planted at stake, so that several grow together at each spacing and are allowed to grow into a wild confused tangle of growth to a considerable height. Much of the 'cherry' is not reached, so it dries on the tree and falls to the ground whence it is gathered. When the crop that can be reached is harvested the trees are stripped, so that green, ripe and over-ripe fruits are gathered together. The harvested 'cherry' is then dried and hulled.

The 'cherries', many of them somewhat earthy from having fallen on the ground, and of different degrees of ripeness, are first sieved to relieve them of loose earth and then heaped together on barbecues to which they have been transported by various means. They are laid in thick layers to dry, being turned with wooden rakes and shovels while they are drying. Naturally the fruit ferments and becomes rank, and it is during this rough-and-ready method of harvesting and drying the cherry coffee that the bean obtains its coarse flavour which the trade recognizes and classifies as 'Brazilian' or 'hard' coffee.

Not all the Brazilian coffee is so treated and despite the conservatism of the people, increasing quantities of coffee are being pulped and treated by the wet method to procure a mild and thus a higher-priced product.

Harvesting Robusta Coffee

That it is possible to dry and cure cherry coffee without producing hard coffee is proved by the fact that the Uganda, Tanganyika, and other robusta

coffees are not classified as hard coffee in the London or world markets London coffee brokers have contended with the Kenya merchants who erroneously refer to native robusta coffee as 'hard', and they state that a disservice is being done to our Colonial robusta coffee whenever it is referred to as such.

Robusta coffee is not hard coffee merely because it is robusta, for robusta is a mild coffee classed as inferior to mild Arabian coffee and used chiefly as a filler. It might, of course, become hard if it were harvested and dried as the Brazilian Arabian coffee is treated. Some of the robusta cherry coffee of East Africa was at one time dried on matting placed upon the ground, but instruction has long since taught the native planters to dry their cherry on staging, on clean rock surfaces or cement floors, and not let it come in contact with the earth.

The robusta coffee cherry of Uganda and Tanganyika is picked only when it is ripe, but the trees belonging to the African farmers grow so large that much of the cherry is allowed to ripen and dry on the trees, whence it is shaken down on to matting laid below. Both the fresh and partially dried fruits are then fully dried in thin layers in the proper manner so that the fruit does not ferment.

Some of the wealthier native growers have small machines of their own in which their dried cherry is hulled, others use locally-made hullers of hardwood faced with tin, which are ingenious enough to last some while. Some hull their dried cherry by placing it in wooden mortars and pounding it with a large wooden pestle, though many of the beans are broken by this treatment. Bukoba natives may be seen laying their dried cherry on a flat rocky surface, and then hulling it by dragging a large rough stone attached to a rope over it to rub off the pericarp. Most of the Uganda robusta is bought as dried cherry and hulled in local curing works.

Plantation robusta coffee in Uganda is almost invariably prepared by pulping the ripe cherry and fermenting the parchment in the usual way, for not only does this method result in a better appearance of the bean, but it would be quite impracticable to dry large quantities of coffee in cherry.[24] If this were attempted then it might become a 'hard' product. Dry fermentation is used and is complete in about sixteen hours, after which the parchment is washed, drained, and sun-dried on trays or concrete barbecues. Rotary dryers are used on some of the larger estates, especially during the peak time of harvest, but sun-drying takes only eight to ten days in Uganda in fine weather. The plantation 'washed' robusta coffee usually commands a premium over that from the native-produced sun-dried cherry coffee.

The cured beans of robusta coffee differ from Arabian coffee in several ways. They are rarely of the same size and usually smaller, though some forms of robusta coffee can produce a bold product. The beans are not so long. They are rounder except on their flat sides where the tips may curve inwards. They are browner in colour and the silverskin clings more tenaciously to the beans. It is very noticeable that any coffee prepared by the dry method has the silverskin closely adhering to the bean, whereas the process of fermenting and washing appears to loosen it considerably.

The Flow of Coffee by the Dry Process

It might be thought that if cherry coffee is to be picked and dried and after-

wards hulled, it may not be so necessary to be over-careful about the stage of ripeness. Actually the cherry should be picked when it is red-ripe and then dried as soon as possible ready for hulling, in which case the parchment and the dried fruit skin are hulled away at the same time.

The dry process is usually applied to robusta coffee, and as the trees grow so big that much of the ripe cherry cannot be reached, it is permitted to dry on the tree, whence it is shaken down on to matting. Even this may require further drying before it is hulled, and the two kinds should be hulled and sold separately, i.e., the bean resulting from the picked and dried coffee, and that which dries on the tree.

The cherry coffee is dried on barbecues, or on staging erected off the ground made of wire mesh, hessian, palm-leaf matting, or close wicker-work of cane or bamboo. Mechanical drying would not be economical for such a bulky product of which such a large part is waste. A hulling machine is combined with a fan for drawing away the dust and hulls.

Experiments in Kenya designed to test various micro-cultures during ripening and preparation on the liquoring qualities of Arabian coffee, had no significant results. An interesting side issue, however, was that despite a very careful preparation of ripe Arabian cherry coffee by the dry method, including slow drying with daily turning, it was found impossible to produce hulled bean from dried cherry which was rated as good quality coffee. It was allocated lower values for colour, type and roast, and all the samples gave a 'sourish to sour' liquor.[7]

The Harvesting of Liberian Coffee

Unfortunately, the large beans in the big fruits of Liberian coffee can never be classed as high-quality coffee. Even though robusta is superior to Liberian coffee the latter is still not classed as hard, and it has its uses for filling and blending. It has a ready sale when the world supply is short, particularly in Scandinavian countries.

Liberian trees often have fruit in all stages of ripening, and trees may be in flower while ripe fruit is being picked. Since the trees grow large and tall, much of the fruit is allowed to ripen and shrivel on the trees, whence it is eventually shaken down, collected, dried and hulled. The trees begin to bear rather later than other coffees and then yield more heavily than either the Arabian or robusta kinds.

Only red-ripe Liberian coffee can be pulped and prepared as parchment coffee, and because the fruit is so large the pulper must have a special facing to the rotating discs or drums. The loss in weight averages about 85 per cent, since 50 lb. of the ripe cherry give about 4½ lb. of cured beans.

Liberian coffee is grown in Malaya, British and Dutch Guiana, on the Ivory Coast, in the Spanish island of Fernando Po, in Spanish Guinea and elsewhere on the west coast of Africa. The people of Malaya prefer Liberian coffee to any other, and as they grow it for their own use, very little is exported. A few thousand hundredweights are exported annually from British Guiana, mainly to Scandinavia.

The Liberian coffee in Dutch Guiana has a rather peculiar flavour, and the theory is that in the subsoil the deeper roots encounter brackish water which has percolated through from the sea. They were determined to try and improve their coffee, and they managed to some extent by drying the coffee at

a high temperature. They also managed to alter the colour from a pale lemon-yellow to a blue-green, but to their astonishment this coffee then proved unacceptable to the Scandinavian countries where they had become accustomed to the peculiar flavour.

The Harvesting of Excelsa Coffee

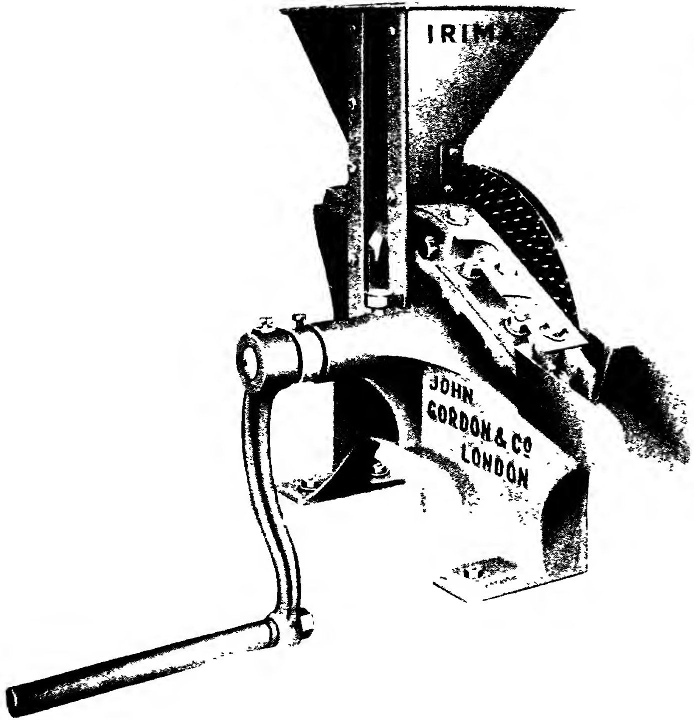
Since excelsa coffee is produced on forest trees it is not possible to pick and prepare the ripe fruit from fully-grown trees, nor can the dried fruit be shaken from the trees except by climbing them and beating the branches as one would a walnut tree. Usually the dried fruits are collected as they fall, though very little excelsa coffee is used or marketed because the quality is so poor. The liquorers classify the flavour as 'unclean', and there would need to be a great deal of selection for quality, if this were possible over more than a century of time, before excelsa coffee could ever be of value as a commercial crop. Attempts at hybridization have often been disappointing because interspecific hybrids seldom prove fertile enough to bear economic crops.

It may be trite to refer readers here to the chapter on the botany of coffee, and that concerned with the breeding and selection of cultivated varieties. Many of the older records and references are based on wrongful determinations, and even today references are made to excelsa coffee when the tree grown is not the true *Coffea excelsa* species at all. The species type grows into a large-sized tree with a clean trunk; any plant that does not do this, and has a shrubby growth, cannot be considered true excelsa coffee. It is more likely to be a form of Liberian coffee, or a natural hybrid, and whereas the fruits and beans of Liberian coffee are generally much larger than any other, there are forms that bear smaller fruits like those of excelsa. True excelsa coffee has fruits and beans about the same size or a little smaller than Arabian coffee. Since the tree sacrifices its lower branches as it grows taller it would be difficult to train it as a shrub.

Coffee Curing

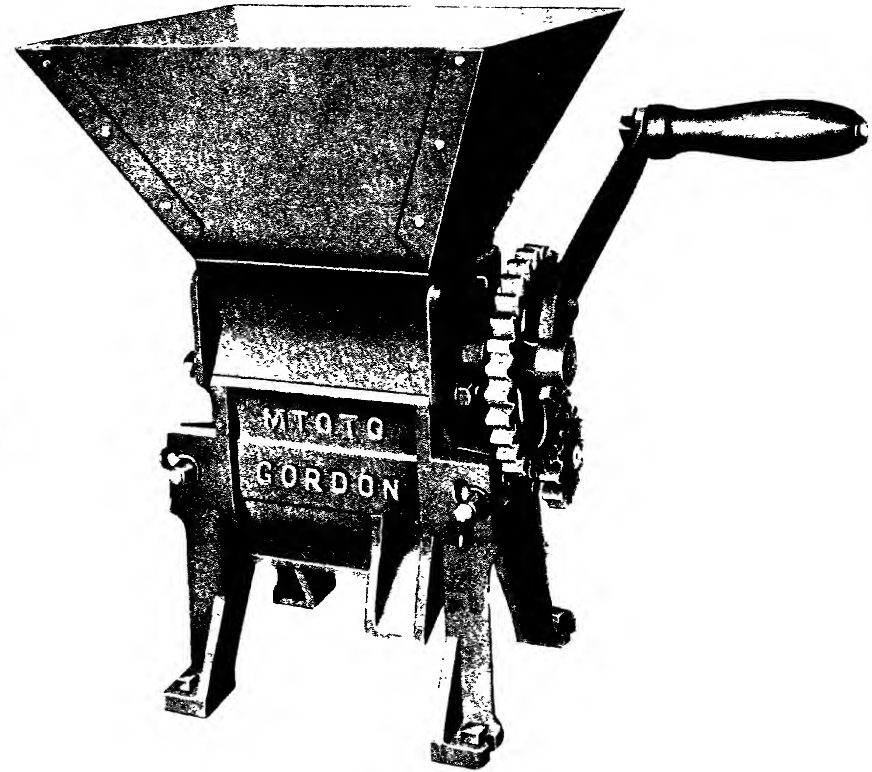
Curing is the treatment of supposedly dry parchment or cherry coffee through all stages of husking, hulling, or peeling, and the polishing and grading of the bean, including hand-picking defective beans, and also the preparation of the raw coffee for market. Curing may be done on a large estate or in connexion with a large co-operative enterprise, and a curing works may be sited in the centre of a coffee industry, in a town, or at a port where the coffee is exported or imported. To save freightage, coffee is usually cured before it is transported any great distance. Large curing works will have facilities for drying coffee if it happens to be a little moist.

The hulling of parchment coffee is called shelling or peeling. There are several types and sizes of machine. The parchment covering and the silverskin are removed and the bean is polished, either at the same time or in a second machine working in tandem. Adjustment is necessary for different kinds of coffee and two machines are normally used, one for shelling and the other for polishing. The normal shelling or peeling machines, especially the larger ones, have no means of releasing the loosened husk and dust before the coffee is discharged from the machine, and if too much pressure is exerted the dust is apt to be forced into the surface of the beans. There is more friction and



By courtesy of John Gordon & Co

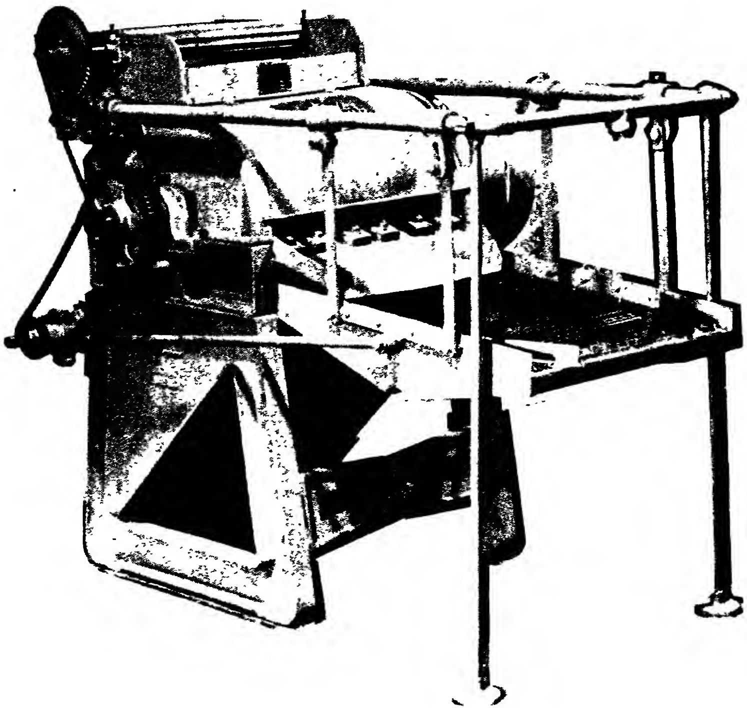
(*a*) 'Irima' (baby) disc pulper



By courtesy of John Gordon & Co

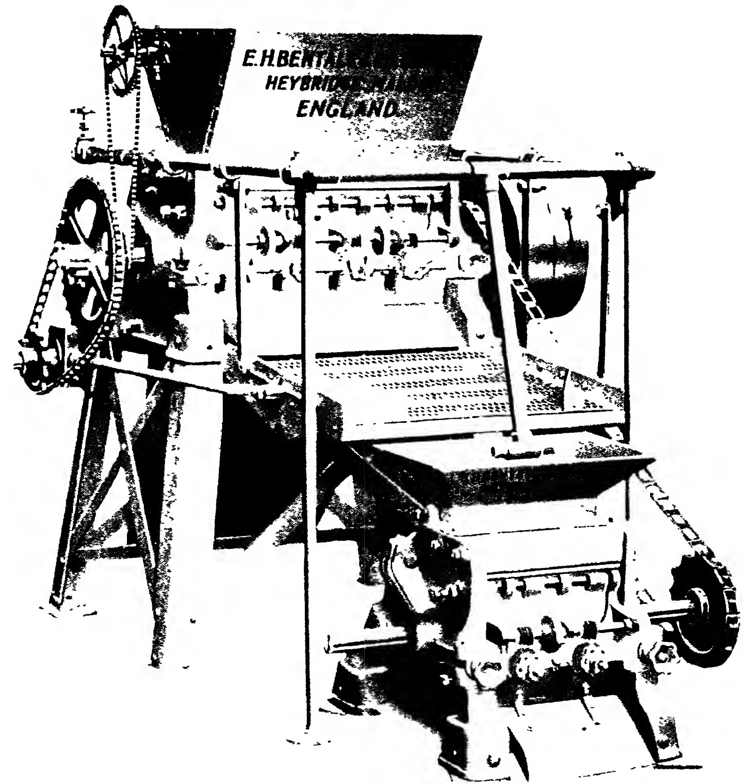
(*b*) 'Mtoto' (baby) breast pulper

PLATE XLVIII



By courtesy of E. H. Bentall & Co. Ltd

(a) Bentall's disc pulper with shaker sieve



By courtesy of E. H. Bentall & Co. Ltd

(b) Bentall's breast pulper with shaker sieve and repasser

PLATE XLIX

power required to shell damp coffee, so the beans tend to heat and lose shape. Machines with phosphor-bronze parts instead of cast iron are said to enhance the blue-green colour of the bean.

A sheller cannot be used to hull cherry coffee satisfactorily. Instead, a huller is used to extract the dried beans from the dried cherry, though it may be used to shell parchment coffee before polishing. In a hulling machine manufactured for the purpose of hulling dried cherry coffee the lower part of the cylinder is perforated allowing some of the dust and husks to escape before the coffee is discharged at the end of the machine. Hulled coffee needs polishing afterwards.

The polishing of coffee beans can be understood to mean two things: (*a*) the removal of all traces of silverskin, and (*b*) putting a shine on the surface of the bean. A shiny surface makes the bean look attractive and clean, though coffee is sold more on roasting and cupping qualities today, than on appearance. It depends, to a considerable extent, on the market.

Beans extracted from dry cherry coffee, and especially from the Uganda robusta coffee, are heavily coated with silverskin closely adhering to the bean and no ordinary polishing machine will remove it. The silverskin must be moistened, and for this a machine known as a 'washing machine' is used. This should not be confused with the washing machines in use after wet parchment coffee has been fermented.

The clean coffee beans to be 'washed' are intimately mixed with damp coffee husk or damp sawdust which must, of course, be clean and neutral so that no taints are acquired; alternatively, the coffee beans may be sprayed with water. The coffee is then given a hard rubbing by beaters in a vertical perforated drum, an operation which is highly skilled since every batch of coffee must be tested before 'washing' to determine the exact amount of moisture to be applied.

Hulled, shelled, and polished coffee must then be graded, and here again there are several makes and sizes of machinery, and various screens to alter grading to suit special markets and kinds of coffee. The flow of coffee in a curing works is by gravity from a top floor to a lower one, and then by mechanical elevators back to the top floor and down again, followed by delivery to lorry level in the street, though, if it is at all possible, it is advisable to have the coffee make only one trip downwards from the top floor to ground level.

Curing coffee is an expert job and the plantation or co-operative society must be of considerable size to make it advisable and worthwhile to cure its own coffee.

MACHINES

Generally speaking one finds British machinery used in all the coffee-producing countries, some French machines in the French Colonies, and some American machines in Brazil and Central America. British coffee machinery preponderates in the world and gives general satisfaction because of the long experience and solid workmanship that goes into the making of the machines. The older-established British firms go back to the late eighteenth and early nineteenth centuries. Many of the old ideas have been copied and, curiously enough, the main mechanical principles are much the same today as when they were first invented. Machines differ from firm to

firm mostly on account of refinements, the more convenient placing of nuts and bolts, or of adjusting apparatus.

Mr. John D. Gordon states that the breastplate of the present-day barrel or drum pulper was patented by his grandfather in 1858. This is now in public domain and is still found in every make of coffee pulper of similar action. The grooves or channels down which the coffee cherries pass are set at an angle from top right to bottom left if the machine is viewed from the front, and every breastplate today is similar; none have the grooves running from left to right.

The four notable British firms manufacturing coffee machinery, arranged in alphabetical order are Messrs. E. H. Bentall & Co. Ltd., Heybridge, Maldon, England; Messrs. Davidson & Co. Ltd., Sirocco Engineering Works, Belfast; Messrs. John Gordon & Co. 165, Dashwood House, 69, Old Broad Street, London, E.C.2; and Messrs. Wm. McKinnon & Co. Ltd., Spring Garden Ironworks, Aberdeen, Scotland. There are also French and German makes and two firms of note in the States, i.e., Marcus Mason & Co., Inc., Westboro, Mass., U.S.A., and the Squier Corporation, Buffalo, New York, U.S.A.

COFFEE PULPERS

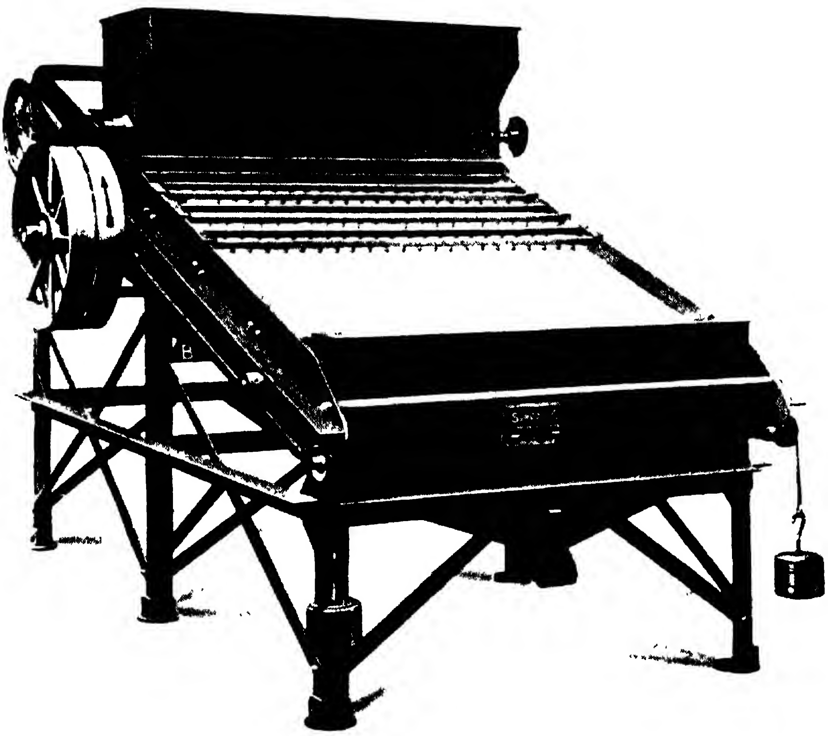
Coffee pulpers range from small hand-operated 'baby' pulpers, and small power-operated re-passer pulpers, to the larger hand-operated or power-driven machines. There are two main kinds: the horizontal drum or barrel pulpers, and the vertical disc pulpers.

The barrel or drum type of pulper has a sheet of copper attached to its rotating drum with projections punched in it, of various designs and sizes according to the kind of coffee to be pulped. The drum rotates against a breastplate in which there are slotted openings through which the parchment beans escape. The cherries are directed by the slots in the breastplate until they are squeezed to free the beans. The slippery beans shoot out of the escape apertures while the skins are dragged down and away to the back of the machine by the punched projections on the drum.

The disc pulper may have the same punched copper sheeting attached to both sides of each disc though in Kenya they now prefer cast-iron discs with the bulb projections cast on the surface. The cherries are brought into contact with the discs so that the beans are separated in a similar way and the empty fruit skins dragged beyond. The pulpers are enlarged by having more slots and bigger and longer drums, or multiple discs as the case may be.

A pulper should always be set to take the average-sized cherry, and a preliminary trial with a small quantity is always desirable to determine the correct setting. If the speed is too high, too much pulp may emerge with the beans; if it is too low, then output will be inadequate from the economical point of view. The rate of feed must be adjusted, starting from zero and increasing the flow of cherry until the rate is found adequate, but not so fast as to crowd and choke the pulper.

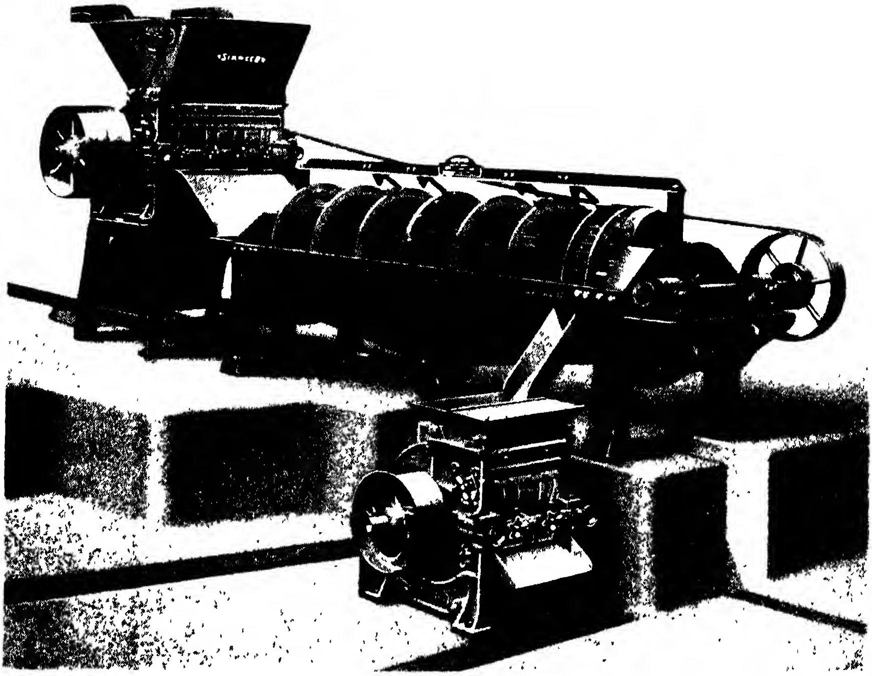
Output and cleanliness of pulping depend on whether picking is done properly and on the kind of coffee and the climate of the country. Berries are drier and harder-skinned in areas of short rainfall and then require a more drastic treatment. The designs of punching in the drums and discs are made to suit different species of coffee and kinds of cherry. The makers should be fully informed and consulted concerning the cherry their machine will have to



By courtesy of Davidson & Co. Ltd.

Sirocco peaberry separator

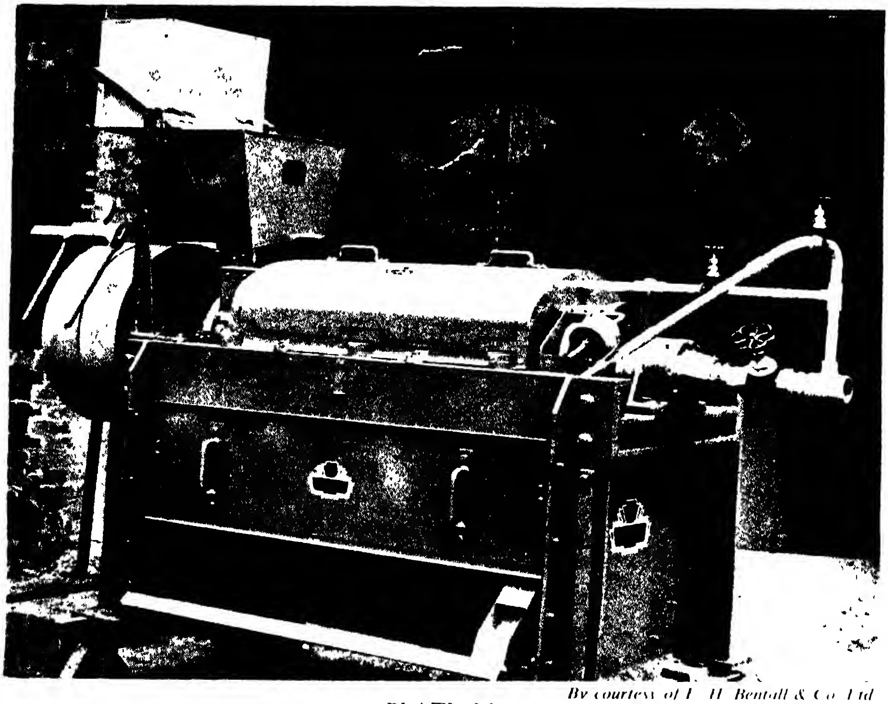
PLATE I



By courtesy of Davidson & Co. Ltd

(*a*) Breast pulper, rotating separator and a repassing machine

(*b*) The Aquapulpa. This will pulp ripe cherry, eliminate the mucilage and wash the parchment clean in a continuous operation. It will also accept parchment from ordinary pulpers and prepare it ready for drying. The makers state that the machine renders fermentation unnecessary



By courtesy of E. H. Bentall & Co. Ltd

PLATE LI

treat. Re-passers should be adjusted to take the smaller sizes of cherry which pass through the main pulper.

SEPARATORS

Separators are used to separate the larger pieces of pulp which pass through the main pulper, and also the imperfectly pulped cherry of small size. They are of three kinds: (*a*) the flat oscillating sieve at a varying incline which delivers the unpulped cherry direct to a re-passer, while the parchment falls through the sieve on its way to the fermenting tanks; (*b*) a rotary horizontal sieve attached to the pulper into which the pulped coffee falls. This is installed in a trough so that the lower part of the sieve is immersed in water. The heavy pulped bean passes through the sieve and escapes at the bottom, while a spiral plate within the sieve pushes the unpulped coffee and floaters along to a high-level escape at the other end of the separator. Sufficient water must pass constantly into the trough to keep it filled and supply a surplus to carry away the separated coffee. The third type (*c*) is again a rotary sieve mounted on an incline so that the sieved-out material falls by gravity out at the lower end. This sieve is not mounted in a trough.

The unpulped cherry is directed afterwards to a re-passer machine. It helps with all three types of machines if water is plentifully sprinkled from overhead to prevent the sticky parchment adhering to the sieves.

MACHINES FOR WASHING FERMENTED COFFEE

Washing machines are of two kinds: (*a*) Vertical cylindrical tanks with a central vertical revolving shaft on which paddles are fixed; these pass through stationary bars bolted to the side of the tank. With a flow of water the light bean can be floated away. Washing takes about ten minutes, but though the machines may vary in size they must be charged, emptied and recharged. (*b*) Horizontal cylindrical machines, said to be continuous in action and to have better outputs, do not appear to be so much in favour.

MECHANICAL DRYERS

Dryers are also made in varying sizes from quite small affairs to giant twin-cylinder rotating drums that will take charges of wet coffee up to more than 200 cubic feet or about six tons in weight. Much larger dryers can be supplied if required, but difficulties are encountered with dryers taking more than 320 cubic feet of wet coffee.

Originally dryers were of two kinds: the Guardiola dryer invented by Don José Guardiola, and the Okrassa dryer invented by Don Roberto Okrassa. The first made use of steam for heating the air; the second used direct heat, though both were immediately available with air heaters using either steam or direct heat. Nowadays there are a great many designs and makes incorporating these systems and sold under varying names. A useful tip is to lag all hot air piping with asbestos rope to avoid loss of heat. Care should be taken to empty a dryer completely before it is recharged with coffee.

PEELING AND POLISHING

The original and popular machine for shelling or peeling parchment coffee

consists of two large-diameter wheels fixed one at each end of a horizontal axle, and the axle is fixed in the middle to a vertical revolving shaft. The wheels thus run round and follow each other in a circle. They are arranged to run in a narrow circular groove or trough which is charged with parchment coffee, and the wheels are so hung that they touch, and rub, and break the parchment shells without resting on the coffee. The shelled coffee is then passed through a blower.

Parchment coffee should be dry and cool before it is put through a peeling machine. Here again there are different makes and sizes of machine but they generally follow the same principle. They need adjustment at first to the kind of coffee that is passing through and the makers can be relied upon to give the necessary instructions.

The Smout peeler was the first of its kind to be introduced, and was invented by a Swiss named Jules Smout. Mr. John Gordon has informed the author of correspondence with Smout's grandson. It appears that Jules Smout invented the machine and many others when he was domiciled in Guatemala, where, curiously enough, the two dryers were invented.

Cast-iron machines may be used for hulling or peeling but it is usually considered that the working parts of polishing machines should be made of phosphor-bronze. There seems no doubt that phosphor-bronze polishers improve the appearance and enhance the colour of the bean. Before polishing became general, there were markets which used indigo dyes to colour up faded beans and Carnauba or Brazilian wax to give them a polish. Such adulteration was prohibited by law in Britain, hence mechanical polishing became more efficient and phosphor-bronze was used in all the big curing works for the cylinder and screw cones and other working parts in contact with the bean. Coffee that has been shelled for some while can never be given the same brilliance. The coffee is warmed when the outer shell is being removed and it is advisable to polish at once before the beans cool.

HULLERS

These machines, so often called 'Africa' hullers, will hull parchment coffee but they are generally used to de-husk or hull dry cherry coffee. There are again many makes and sizes generally of comparable design in so far as the principle of working is concerned. Arabian coffees are always polished during or after peeling or hulling, but other coffees that are hulled from the cherry are seldom polished to any great extent.

Dry cherry coffee may contain extraneous matter such as sand, small stones, bits of twig and even small pieces of metal, and as these would damage the machines and the coffee during the action of hulling, an elimination or screening machine is often used in large works to get rid of such foreign material.

When small machines are not fitted with fans to take away the hulls and dust, separate winnowing machines may be used. These are often found of value for winnowing other agricultural products.

COFFEE GRADERS

Though some are used for grading parchment and act also as eliminators, most of the grading machinery is made to grade the actual bean according

to market requirements. Graders work on different principles, but the usual action in the first place is to pass the coffee along a rotating horizontal sieve wherein the holes or bars vary to permit the recognized sizes of beans to fall through as they proceed from one end of the grader to the other. A great deal of coffee, especially that marketed in the United States, is sold by standard screen numbers. Most of the Brazilian coffee is sold by these numbers and is graded by width alone.

Grading otherwise is three-dimensional as far as the flat beans are concerned, i.e., width, thickness and length, whereas peaberries are graded according to width and length. The coffee is graded first for width, then thickness and afterwards for length; this is so that the longer beans that are firstly classified among the seconds, may be graded out during the second grading and added to the firsts. By separating the greatest possible percentage of firsts, a correspondingly higher price is obtained.

The method of grading in India is first of all to size the coffee by means of round holes, and then take each grade so produced and pass it through a second cylinder with slot holes to separate the peaberry from the flat beans. In the London type of grader the beans are first graded by their thickness and then by width, and the grade of peaberry is made while the elephants are eliminated. The peaberries are not graded by length.

The rounded peaberries can be separated from the flat beans in a comparatively easy way if the coffee is thinly spread on a canvas belt which slopes and moves upwards, and on which the flat-sided beans come to rest. They are carried upwards, whereas the rounded peaberries roll downwards in the opposite direction. It is rather a slow process.

A grading machine cannot deal with all the kinds of coffee produced by various countries without altering the mesh openings and perforations. A supplier must be informed, and acquainted with the special requirements of the countries and coffees concerned. Provision is made so that the perforated screens may be changed with comparative ease.

Handpicking

There are machines such as the Catador, which uses an air current and classifies the coffee passed through it by the density of the beans. They save labour, and where a sample of beans has a great many defectives, blowing it through a catador will produce good results when hand-picking might not prove economical.

No mechanical grader can separate beans which are off-colour on account of insect or other injury. Handpicking must be resorted to at the end of curing to render all the grades ready for market. This is best done by trained hands sitting on each side of broad moving belts of canvas on which the beans are thinly spread, and from which the imperfect ones can be snatched up and deposited in trays or bags alongside the operatives.

It will be seen that in a curing works the coffee must flow from one machine and one operation to the next, and a great deal of acumen is exercised to see that awkward movements are reduced and carried out mostly by mechanical means.

The Characters of Cured Bean

Coffee is sampled and tested for its qualities before auction or sale. Liquor-

ing is a profession that needs long experience, a delicate and trained palate, an almost uncanny ability to distinguish, in some cases by the mere taste, the exact origin of the coffee. Liquoring safeguards the buyers and assists producers because a coffee which otherwise looks first class may be found to carry a taint which loses price and makes it of little use for blending with other high quality coffees.

The raw coffee is first examined and classified, and though its plumpness and weight and evenness are all considered, the colour is the most important of all. Planters should aim at obtaining a bluish-green to greyish-green colour and avoid any hint of brownness. Preference is given to this colour because many years of experience have taught coffee dealers that it is only in coffee beans of this colour that the finest liquoring qualities are found. The blue colour of under-dried coffee is dangerously misleading, because it soon fades and the beans deteriorate. At all costs the coffee must be dry.

Brownness is generally caused by some fault during drying, or maybe by rain and humid conditions at that time. According to some reports, mechanical drying may cause a degree of browning[3], but if it does then the operator should try to discover what is wrong. He may be trying to dry his coffee too rapidly by using too high an initial temperature, or start quick-drying after a period of sun-drying. It should not be forgotten that mechanical drying is often somewhat reluctantly used on estates which mostly depend on the cheaper process of sun-drying; the dryer is used only when the weather is such that sun-drying has become most difficult. It may be started too late, or the colour of the coffee have been affected in the drying trays beforehand.

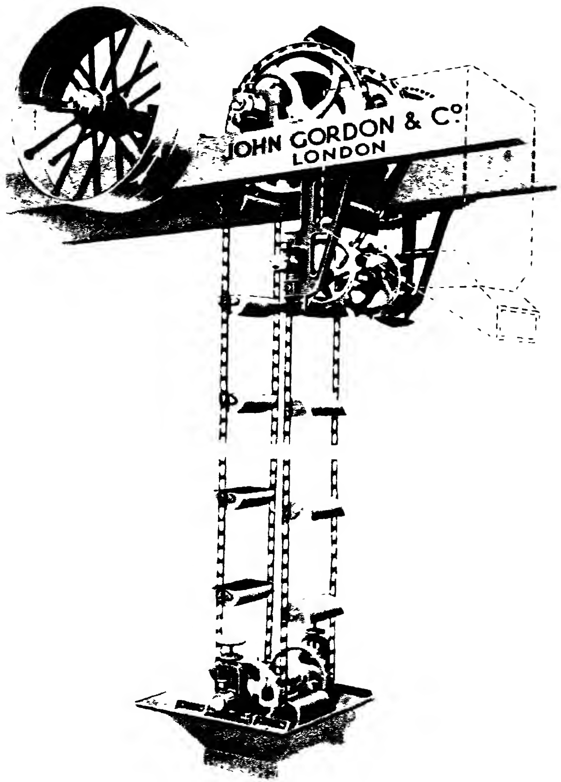
There is the old adage that 'a good workman never blames his tools', and mechanical drying is a useful tool that has been installed for many years in countries which produce the finest quality coffee. Planters in Kenya are recommended to note[3] that 'estates which consistently produce coffee of a fine quality almost all appear to do their drying on raised tables, . . . in preference to using barbecues or ground sheets.'

If the parchment is dirty, the colour and polish of the bean may be affected during peeling, and the very fact that it is dirty hints at under-fermentation. Coffee that has been picked over-ripe, or has been over-fermented and mixed with too much pulpy skin, tends to have a brownish colour in the bean. Few have studied the temperatures of fermenting coffee. It is curious that high quality Arabian coffee is correlated with high altitude, and a temperate climate, where fermentation takes a long while to complete. In warmer climates at lower altitudes fermentation is rapid, and may take no more than twelve hours. The author suggests that temperatures in the fermenting coffee may be much higher during warm weather or at the lower altitudes, and be the root cause of much browning.

Some coffees are spoken of as being 'ragged'. Bean from the Harrar Abyssinian seed often has a ragged appearance, and so does that from drought-stricken regions. The centre-cut or crease is not straight or properly closed, and the bean has a starved appearance.

The terms immature and 'coated bean' refer to light, starved beans badly coated with silverskin. This can be due to several causes, and there are some regions in particular, which produce coffee that tends to retain its silverskin closely adhering to the bean.

According to the variety of coffee grown, and the environment, there are



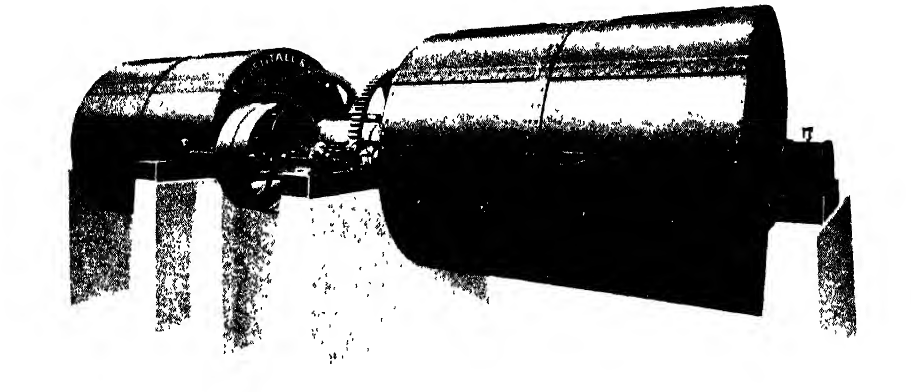
By courtesy of John Gordon & Co

(*a*) Perfect discharge elevator for wet parchment coffee

By courtesy of John Gordon & Co

(*b*) 'Bukoba' small hand-huller

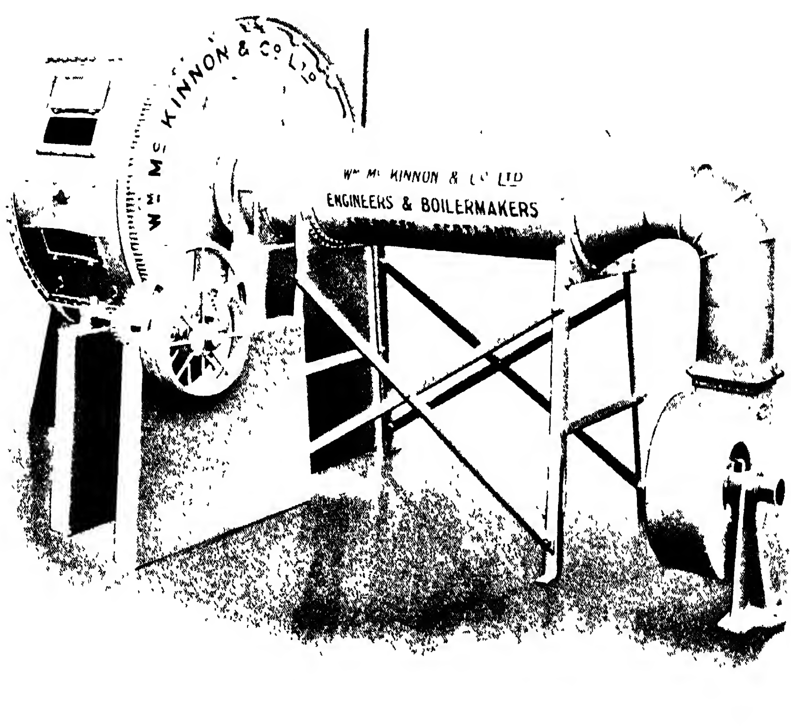
PLATE LII



By courtesy of E. H. Bentall & Co. Ltd

(a) Bentall's 'Guardiola' twin-cylinder coffee dryer

(b) McKinnon's 'Okrassa' type coffee dryer with 'Vizcaya' steam heater and ball-bearing fan



By courtesy of Wm. McKinnon & Co. Ltd

PLATE LIII

recognizable differences in the shape and size of the beans. There may be boat-shaped bean, with the tips tending to curl inwards: some kinds are plumper and more rounded, others have longer beans, and some have beans tending to be pointed at one end. A roundish heavy bean with a fairly straight centre-cut is typical of bourbon coffee grown in a good neighbourhood.

Blotchy bean is caused by uneven drying, usually because the parchment has been heaped too thickly on the trays in a moist state, when the rate of harvest has overwhelmed the equipment available for drying.

The defectives are sometimes peculiar to the region of origin, but are often universal. Most defectives are eliminated by hand picking at the end of the curing process, if there are not too many in a sample. Antestia-, or insect-damaged beans, can be too numerous and throw all the coffee into low grade. A bad infestation of Antestia bugs which pierce and suck the juices from the immature fruit, produces an abundance of light and shrivelled bean, crinkled and ragged. Bean-boring insects leave obvious holes and burrows in the beans, and patches of decay which may have a pinkish or bright green discoloration.

Pulper-nipped beans are sometimes discoloured because of oxidization during fermentation. 'Foxy beans' are those with a reddish colour due to over-ripeness or damage. They may have picked up effluent from the fermenting tanks or they may not have been properly washed. Over-ripe beans tend to have the appearance as those which are hulled from dried cherry, and have the same flavour. 'Stinkers' are those that have been overlooked when cleaning out the tanks and washing channels, so that they have been fermented a second or a third time. Beans known as 'Ambers' are smooth and yellowish, the cause being unknown, and 'blacks' are due to a physiological disease.

Notwithstanding what has been said previously about co-operation and the bulking of coffees in different regions, this is advisable only when there is strict and progressive control throughout an area and when a local grading scheme is strict. Bulked coffee may retain a regional character but be uneven in character. Its only attribute is standardization, so that buyers have confidence in the grade, together with the fact that bigger parcels of the one grade may be offered for sale.

The bulking of coffee on the other hand tends to lower quality as a whole. It destroys the initiative of those who strive to obtain superfine quality and a name for a special mark. It robs the market of the ability to search for, and pay high prices for, the superlatively fine coffee that a region might be able to produce. Like the slowest ship in a convoy, progress is tied to the lower quality producers, who may not be too keen or financially endowed to permit improvement in later years. In times of slump, the man who produces the very best will find an easier sale.

Roasting Coffee

The type of roast refers to the general appearance of the roasted bean, and a brilliant or bright type of roast should be aimed at, because experience has shown that a roast of this sort usually gives a satisfactory liquor. The centre cut is the dividing line or crease running down the centre on the flat side of the bean, and silverskin may adhere at this point. After roasting a fine quality coffee, the centre-cut stands out clean and white, and usually accompanies a bright roast. Brown centre-cuts are not considered good. 'Even' berries are

those which are roasted with every bean bright and brilliant, with the centre-cuts all white or not too irregular, with few or no defectives.

The terms 'softs', 'pales' or 'semi-pales' in roasted coffee refer to the beans or 'berries' that have no grain, or are of a dull, yellow colour. 'Full pales' stink when crushed or ground. 'Pales' may come from immature or drought-affected coffee, and are berries with little or no grain. Amber beans and 'green parchment' beans often cause 'pales' in the roast.[3]

It is trite to remark here on the terms used in the coffee industry. In the field, the coffee fruits which in truth are berries, are referred to as 'cherries'. The seeds of the fruit are miscalled on a world-wide scale the coffee 'beans' of commerce, whereas they are not beans at all. Immediately the raw coffee goes to the roasters, the hulled seeds or 'beans' are then termed 'berries', so the whole nomenclature, though well-known to the trade, is topsy-turvy. Unless otherwise stated, the character terms for raw, roasted and liquored coffees are those used in the London and Colonial markets. Many other different terms are used in North, Central and South America, and on the continent in Europe.

Mottled berries during roast are caused by the uneven drying of the coffee. They are not always detrimental to cup values, provided the coffee is fresh. Ragged and ugly berries come from mis-shapen beans, and 'open' berries are those where the centre-cut tends to widen apart during the roasting process.

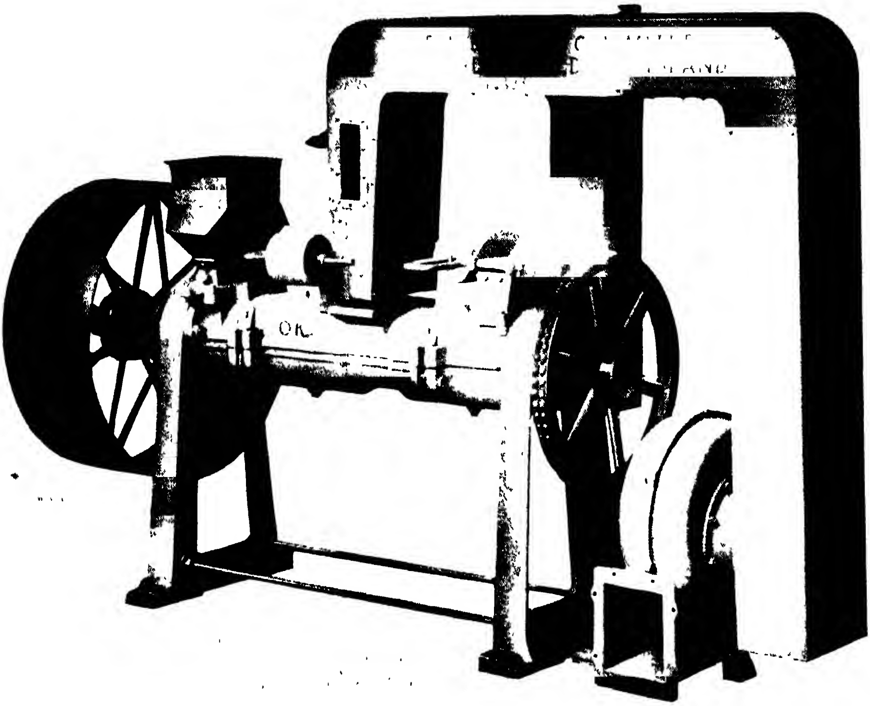
Taints and Liquoring

Tainted is the term used to denote the presence of flavours which are foreign to a good clean liquor. It is a term applied in a general sense to flavours that cannot be included among those that are easily recognizable and therefore given special names. Good clean coffee can easily pick up a taint from other cargo in a ship's hold, and since coffee cannot be shipped alone, and a mixed cargo consists of such things as odoriferous hides and skins, perfumed cloves, and sisal which has an indescribable odour of its own, it is astonishing that coffee does not pick up more taints on its way to the world's markets. It reflects great credit on the manner in which stowage is accomplished.

The 'woody' flavour peculiar to old coffee kept in storage, may well be picked up from the pungent woody odour of the fibre sacks in which it is stacked closely, in great bulk in hot warehouses.

A 'common' flavour means a poor liquor lacking acidity, and a 'harsh' flavour is self-descriptive, and said to be found in coffee of a ragged immature appearance. It is suggested that certain trees, not in good health, with a starved and drought-stricken appearance, may give coffee of such a flavour. The crop from these should be picked and treated apart if this can be managed.

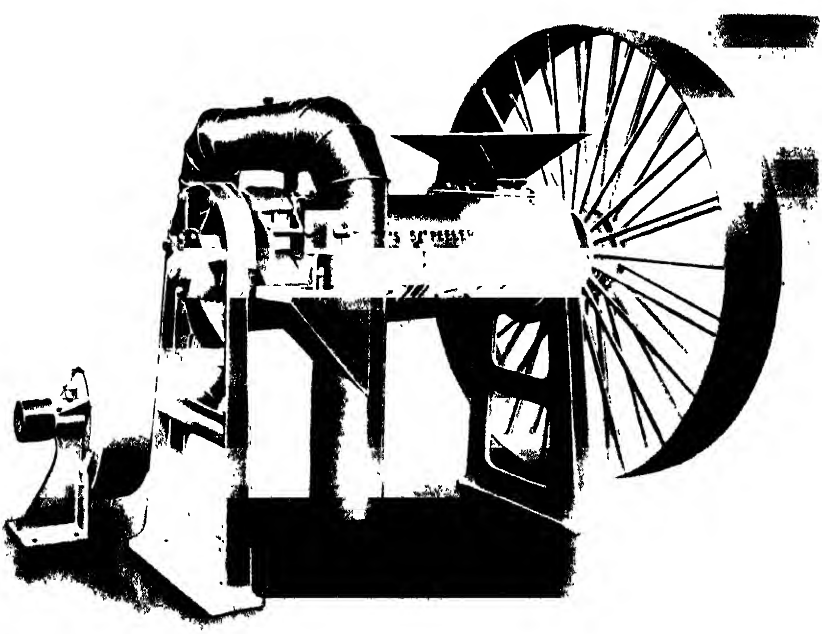
'Earthy' coffee is said to be caused by faulty drying in contact with the earth or grass. All coffee should be sun-dried on trays or staging at least two feet off the ground. 'Musty' coffee is produced (*a*) when the drying equipment is overwhelmed and wet coffee is piled too thickly to dry in the sun; (*b*) when, to give room for successive washings, half-dry parchment is stored in bulk for a while, perhaps in a crib; (*c*) when coffee is not perfectly dry and is then stored in a damp store, or thoroughly wetted by rain on the road to shipment and then stowed while wet.



By courtesy of E. H. Bentall & Co. Ltd.

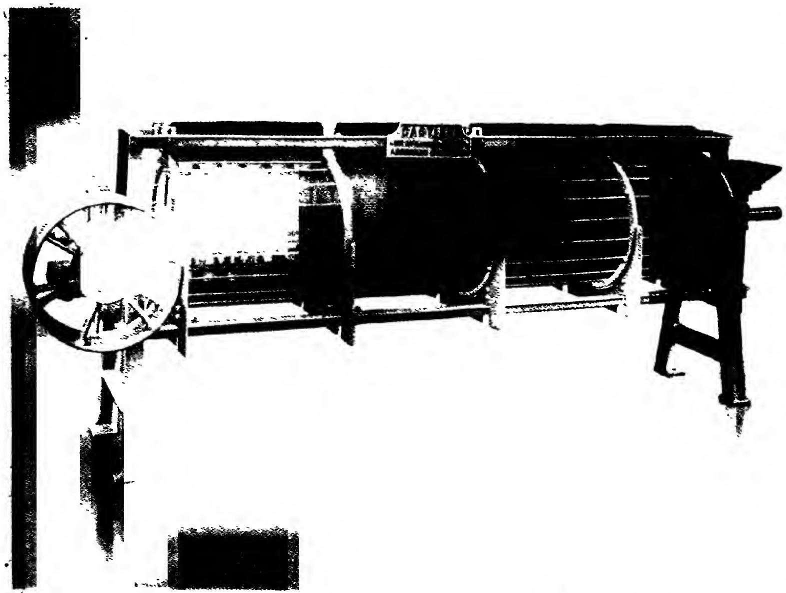
(*a*) Bentall's 'Okrassa' sheller and polisher machines

(*b*) McKinnon's No. 1 size or 54 in. 'Smout' peeler and polisher



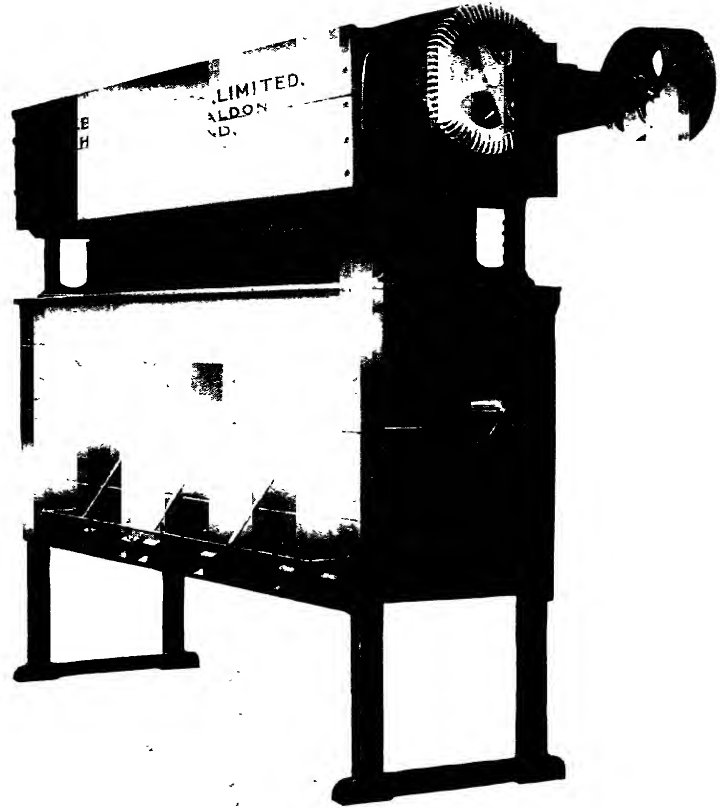
By courtesy of Wm. McKinnon & Co. Ltd.

PLATE LIV



By courtesy of Wm McKinnon & Co. Ltd.

(*a*) McKinnon's Castilla coffee grader



By courtesy of E. H. Bentall & Co. Ltd.

(*b*) Bentall's 'London' coffee grader

PLATE LV

A 'fruity' flavour is suggestive of fermenting fruit pulp. The early crop from high-altitude coffee in Kenya is said to be slightly fruity, and this may be caused by particular soils, climatic or growth conditions—perhaps because the parchment coffee takes longer to ferment. Over-ripe cherry, or some fault in preparation, may account for it, and it is often an early stage of a less objectionable form of the flavour known as 'sourish' or 'sour', an unpleasant flavour similar to that produced in coffee extracted from dried cherry. Faulty processing, and a continuation of the ferment during drying may be the cause, delayed drying and heating, or too many skins fermented with the parchment. Discoloured pulper-nipped beans may contribute to the flavour.[5]

A 'greenish' or 'green' flavour, said to be suggestive of hay, is common in early pickings, and the flavour may be lost a few weeks after curing. It is seldom present in coffee that has been thoroughly dried. 'Grassy' coffee is an exaggerated 'greenish' flavour and is very pronounced, invariably caused by improper drying or by damp storage after drying. In the 1910–20 period, much of the Uganda Arabian coffee was labelled as grassy, for it was grown at lower altitudes and under humid conditions where the robusta coffee has superseded it, and the equipment for drying was often inadequate.

'Strong' coffee is a term used to denote an unbalanced strength, sometimes unpleasant, and said to be peculiar, perhaps, to soil, climatic conditions or method of growth. Amber beans and green parchment, the causes for which in raw coffee are at present unknown, both produce a strong flavour.

'Unclean' coffee is said to be almost 'foul'. The term is given to coffee of the excelsa species, and may be found in hybrid coffees and certain Liberian strains. In Arabian coffee it can be caused only by bad processing, storage or transport. 'Foul' or 'quite foul' coffee denotes a most objectionable liquor suggestive of rotten coffee pulp, or the advanced stages of fruity or sour coffee. It is invariably caused by faulty preparation or polluted water. It is stated that one badly discoloured pulper-nipped bean is sufficient to give a foul cup to an otherwise good liquor. The best excelsa coffee might be rated unclean, and a poorer quality excelsa as foul coffee.

To conclude the guidance to liquoring terms and the reasons for flavours, and remembering that the terms may differ in the Western Hemisphere and on the Continent, one may say that some of them sound more frightening to the producer than, in fact, they are. The presence of a slight taint does not always affect classification, especially if the raw coffee sample looks good, and the roast has a good appearance. Planters who have gone to the trouble and expense of producing good coffee will not want it ruined by a taint. If a taint is reported, then they should do all they can to discover the cause.

Coffee liquorers who work in their city offices and markets a thousand miles or more from the growers, are, after a lifetime's experience, apt to pretend to a profound knowledge of the growing and producing industry which in reality they do not have. While acknowledging their technical experience, like every other human being they are apt to err. The cause for the taint is sometimes quite different, and something the planter has to search for and discover himself.

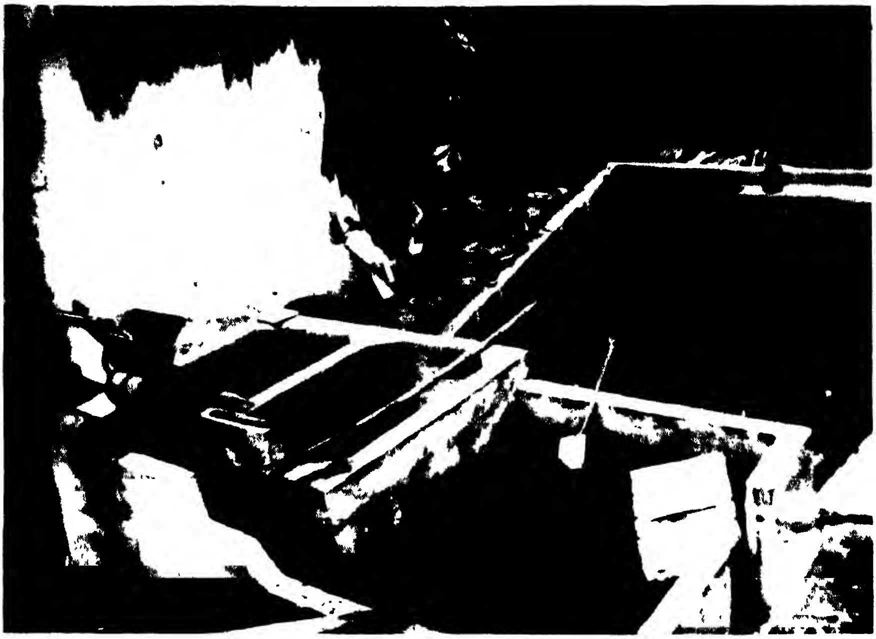
'Black bean' occurs at times among raw coffee and is not due to uncleanliness, but, according to our present knowledge, to a physiological disease. 'Primrose bean,' which has a greenish-yellow coloured silverskin when the parchment is wet, gives a poor liquor in the ultimate test, and is not caused by climatic conditions or by early picking as has been suggested.[15]

'Onion' flavour has been reported at times in some samples of East African coffee, and its cause has been difficult to trace.[16 19] Exhaustive preliminary trials were conducted in 1949–50, the results of which were reported.[16] There appear to be two predisposing factors governing the occurrence of onion flavour: (*a*) a certain seasonal or type of coffee, and (*b*) conditions during fermentation. It seems that when fermentation is prolonged, the more the pulped parchment is in contact with water the more the onion flavour may be developed. Pre-washing, frequent washings during fermentation, and fermenting under water are all likely to encourage onion flavour. However, these procedures may be carried out for some while without causing an onion flavour until a picking or the correlating circumstances of seasonal environment are conducive or predisposed to an onion flavour developing.

If onion flavour does develop, pre-washing, washing during fermentation, and fermenting under water should be discontinued. They are refinements that appear unnecessary in commercial production. During the investigations in Kenya it was concluded that frequent washing, cleaner water and avoidance of over-ripe cherry, when carried out separately, are hardly likely to make any noticeable difference in commercially produced coffee, though in conjunction they may well do so. This gives encouragement to those who are careful in following all-round orthodox treatments, but none to the crank who insists on some particular practice as the key to good quality. One very important finding was made, i.e., that parchment from over-ripe coffee fermented rapidly and was ready for washing in twenty-four hours, whereas that from normally ripe coffee required seventy-two hours in the neighbourhood where the tests were made. This indicates that over-ripe coffee should never be mixed with ripe coffee, since it would become over-fermented within the bulk ferment.

Since a proper fermentation is reputed to have little effect upon the bean, and is only carried out to get rid of the mucilage, insufficient research has been carried out on the biology and chemistry of coffee fermentation. Bacterial organisms must take their part, and these may be of aerobic and anaerobic nature, i.e., active in air, or in the absence of air. Pre-washing and frequent washing during fermentation may have an effect on the sugar content of the mucilage, and on the preponderance of an organism of a particular kind. Moreover, fermenting coffee under water would exclude air and inhibit aerobic action. Too much water may well interfere with the natural act of fermentation which should be assisted and not be deterred or profoundly altered by new ideas. A further note on research in Kenya[17] mentions that under-water fermentation is definitely conducive to the development of the onion taint.

A 'bricky' flavour, similar to that found in certain hard Brazilian coffees, was surprisingly found in some of the mild coffees produced in Kenya, and the incidence was immediately investigated. It had been suggested that the insecticide benzene hexachloride (B.H.C.) was the cause, and at first the authorities were sceptical that a little insecticidal dust placed round the base of a tree could affect the flavour of the coffee bean. Whereas no relation had been proved between the use of spraying of any kind and onion flavour, it was definitely established that the bricky flavour of East African coffees had been caused by the use of B.H.C. insecticides in one form or another. About ten per cent of all coffee estates were affected, and it was decided to advise



By courtesy of the Venezuelan Embassy

(*a*) Use of 'baby' pulper in Venezuela by a small-holder, showing the lay-out of two fermenting and washing tanks, a compound for the pulp waste; and small cement barbecue for drying coffee

(*b*) Filing coffee samples classified by liquorer, Moshi, Tanganyika

By courtesy of Public Relations Dept, Tanganyika

PLATE LVI


By courtesy of Public Relations Dept., Tanganyika

(*a*) Hand-sorting Arabian coffee at the Moshi coffee-curing works

(*b*) Coffee liquoring, Moshi, Tanganyika Territory


By courtesy of Public Relations Dept., Tanganyika

PLATE LVII

planters not to use B.H.C. insecticides until it had been proved that new formulations or methods of application could be used without risk.[18]

Commercial Roasting and Retail

On the whole, the British public are not coffee drinkers, and since World War II, partly because of the need to conserve hard currency, and partly because of the high price of coffee, many have turned to drinking more tea, or their taste has become degraded still lower by the availability of coffee essences in powder or liquid form which contain high percentages of roast chicory. For people who are not discriminating and who care to deceive themselves into thinking they are drinking good coffee, essences and powders are less troublesome to brew and provide a beverage at least as good as, if not better than, real coffee which has been roasted badly and stewed according to the careless British fashion.

Among the many there are the few who are fastidious, perhaps more so than any other people in the world. Though the consumption of robusta coffees is increasing, for the preparation of the aforesaid essences, a large proportion of the coffee imported into the United Kingdom is still of the finest mild Arabian coffee. Perhaps we cannot afford so much of the finest Mexican or Colombian coffee, yet we are still avid customers for the best Blue Mountain Jamaican coffee and the better qualities of East African coffee. Before the war the United Kingdom was renowned as the best customer for the finest mild coffees, despite the fact that our total consumption was less than two per cent of the world's supply of coffee, and despite the fact that we were also renowned for brewing and drinking the worst coffee. The reason was, of course, that much of this fine coffee was re-exported, since the United Kingdom was then the European Mart. Even before World War II, Germany, who had been one of our best customers, began buying direct from Central American producers, in particular Mexico and Guatemala.

Many have admitted that the roasting, retailing and catering trades in Britain require a great deal of instruction in the use and presentation of good coffee. Indeed it has been and still is a worry to our own producers of good raw coffee, for they are naturally anxious that the public should be taught to appreciate and make good coffee.

Though Continentals had given the British public a reputation for brewing bad coffee before the two world wars, their own tastes became debased when they were forced to adulterate whatever coffee they could get with substitutes. It is questionable, nowadays, if the coffee on the Continent is any better than our own.

To begin with our public require to be taught that freshly-ground coffee has no significance. It is freshly roasted coffee that matters for, when stored, it loses its flavour because the aromatic properties are volatile. Naturally the deterioration is more rapid when ground coffee is stored, and to get the best cup value out of coffee, the bean should be roasted and ground immediately before use.

During roasting, the preliminary stages which turn coffee first of all to a golden-yellow as moisture is expelled and then to a russet brown as cracking begins, should be as short as possible, provided the heat is such that it does not scorch the beans. A reduction in heat is required during the cracking stage and until cracking subsides, and then a further reduction in heat should

be made until the required shade is obtained. To obtain even roasting, a rotary roaster is preferable and the chamber should be warmed beforehand and never started cold.

A pale roast is obtained by maintaining a fairly full flame until cracking is well developed, and then, after a few turns with a lower flame, the coffee is ejected. A pale roast gives a better aroma and acidity. The liquor is a bright gold but the fullness of the cup is lost. A slow roast merely bakes the coffee so that the cracking stage is retarded, leading to the mistaken idea that a pale roast has been obtained.

A full roast may darken the ultimate liquid but the fineness of the aroma is lost. Connoisseurs among us maintain that beyond the ordinary and common taste there can be a 'bouquet' or 'scent' found in only the finest quality coffees; this is a very delicate and transient thing which staleness or baking or over-roasting may kill. It is submerged when blends are too coarse.

The best East African coffees with fine acidity are said to be at their best when used in this manner. Others have a characteristic bouquet and a soft richness which are brought into being by a fairly full roasting. Some of the choice Indian coffees produce a fine flavour with a pale roast though these and the better coffees from the East Indies have been valuable mainly for their richness after full roasting.

Other peoples of coffee-drinking nations consider that pale-roasted coffee is uncooked. The aroma and taste, to them, should have the pleasant but slightly charred flavour of a high roast, wherein the quality of a fine coffee can still be perceived but the delicate bouquet is lost. Many fine acid coffees tend towards bitterness in a high roast, while soft coffees of low acidity respond well and Santos coffee becomes palatable. Their flavour is slightly coarse and bricky when moderately roasted.

Roasted coffee should never be permitted to cool in bulk. If it cools slowly the oil in which the aroma lies is sweated to the surface of the beans. It is preferable to cool the berries rapidly by fanning them with a stream of cold air.

Trading in Coffee

This book deals with the production of coffee, so that the marketing which differs so widely in the various centres of sale, and changes from time to time, does not come within its province.

By-Products

PULP

Information is available on the preparation of vinegar from fresh coffee pulp,[6] the average composition of which is said to be as follows:

	Percentage
Moisture	42·66
Volatile Oils	0·112
Waxes, fats, resins	1·184
Tamis	8·557
Raw fibre	27·445
Sugar	9·455
Minerals	3·772
Not specified	6·815

In some coffee varieties the percentage of sugar is higher, and as much as 12·55 per cent in a sample of 'Botucatu' Arabian coffee pulp in a complete state of ripeness. Glucose and sucrose may be identified among the sugars, the percentage of the latter being about 1·75.

To create a rapid and uniform fermentation, the pulp must first be reduced to a mash, after which it must be pasteurized at 75° C. for 45–55 minutes and then inoculated with a culture of *Saccharomyces octoporus*. With the temperature held at from 23–25° C. a good fermentation sets in within twenty-four hours, and reaches its climax on the fourth day. Fermentation is complete after twelve days when clarification must follow. Calculated on the basis of 100 gm. of sugar, an average of 43·5 gm. of alcohol is present. The specific gravity of the liquid is about 1·006, and the acetic acid content amounts to 0·25 gm. or 600 c.c.

When this liquid is acidified in bowls filled with good chips slaked in previously prepared strong vinegar, while the temperature of the acidification room is held at 35° C., the vinegar which results is of a clear Rhine-wine colour. It has a smell resembling pear oil and a taste akin to old whisky, but the taste disappears within three or four weeks and the colour tends to clear.

The vinegar has a specific gravity of 1·015, a total acid content (as acetic acid) of 4·60 per cent, traces of ethyl alcohol, 3·67 gm. of solids and 1·29 gm. of ash in 100 c.c. The soluble proportion of the ash is 0·97 gm. or 75·2 per cent. On the average, the vinegar output is said to be about 74 per cent of the theoretical.

Mash which is not completely ripe when mixed with ripe mash causes the fermentation process to come to a standstill after some hours of slow fermentation, on account of the presence of large amounts of salicylic acid in the pulp. Methenol derived from the pectin in the fruit is present in over-ripe mash. Unpasteurized mash always shows amyl alcohol in the fermented liquid, and during fermentation a strong odour of ammonia is noticeable denoting the bacterial activity on the amino acids.

FLOWERS AND THE PERFUMERY TRADE

According to tests at the Porto Rico Agricultural Experiment Station,[2 20] coffee flowers may be picked at the rate of about 1 lb. per man per hour, and the average extract of oil is about 0·5 per cent on an average. Extraction with petroleum ether by the use of percolation or in soxhlets gave the highest extraction rate, though ethyl ether may also be used. If the flowers were frozen at 2° C. for twenty-four hours they gave a slightly higher yield than did the controls. It is stated that if the absolute commands a price commensurate with other flower absolutes, the product should have commercial possibilities.

Solvent	*Yield percentage*		*Quality*	
	Concrete	*Absolute*	*Colour*	*Aroma*
Petroleum ether...	0·8728	0·5630	Light brown fluid.	Good characteristics.
Ethyl ether ...	0·7009	0·5033	Dark brown thick.	Delicate flowery odour.
Acetone ...	0·5394	0·1997	Very dark brown.	Improved strong odour.

ANALYSIS OF COFFEE BEANS

The following figures are given by Dillingham and Thompson[4] who also give the procedure for extracting oil from coffee beans and list its properties.

ARABIAN COFFEE BEANS—ANALYSIS

Constituents	*Raw beans*	*Roasted beans*
Ash	3·62	3·10
Total nitrogen	2·55	2·22
Protein (N × 6·25)	15·94	13·88
Crude fibre	13·77	17·94
Reducing sugar as dextrose	0·23	0·17
Ether extract—Crude fat	18·24	11·97
Sucrose	7·83	1·87
Starch	5·80	6·76
Caffeine	1·27	1·31
Calculated on a moisture-free basis by Zeffman and Bram. for comparison.		
Ash	3·92	3·87
Total nitrogen	2·21	2·38
Ether extract	14·91	16·14
Conde fat	31·24	25·07
Caffeine	1·33	1·42

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Chapter XIII

THE DISEASES OF COFFEE

Classification and Primary Causes

Diseases of coffee, like all other plant diseases, can be classified under different heads in accordance with their destructive potentialities and the parts of the plant affected. Most of them are encouraged by insanitary conditions or by something in the environment which is inimical to the perfect health of the tree, such as drought, lack of nutrients, primary injury by insect pests, over-bearing and thus a weakness of stamina.

Then, of course, there may be an inherent predisposition or resistance to a particular disease. Resistance should not be relied upon so much that the health of the trees is neglected, because resistance may be broken down or a disease may alter its character by mutation and thus overcome the resistance.

Always one finds diseases more numerous and doing greater harm if the environment is unsatisfactory, or if the trees are weakened. Diseases may flourish among wild host plants or on abandoned plantations which have become overgrown and thus may be sources of infection. In the author's opinion there should be a law in every country to prevent the abandonment of a plantation unless the trees have been uprooted and satisfactorily destroyed beforehand.

Diseases may be of four types, (*a*) aggressive, i.e., they will attack trees whether they are healthy or not; (*b*) potentially aggressive, in other words, quiescent for periods until a temporary change in the environment or the health of the crop permits the disease to break out and spread like wildfire; (*c*) incidental, i.e., emanating from some dead tree stump, perhaps, but not spreading with the swiftness which threatens disaster; (*d*) supplementary, entering through some wound or puncture and unable to cause damage by themselves alone.

A rust disease can be aggressive, a mildew potentially aggressive, a root disease incidental and a coffee bean disease supplementary and introduced by the puncture of a sucking bug.

A coffee planter should be aware of, and be fully prepared to take action against diseases within the first two categories. He should watch for and be ready to deal with the others, realizing that if a disease is taken before it has been allowed to spread, then control may be established and be much less costly.

For similar reasons it is necessary to know the predisposing factors, the early symptoms and the seasonal potentialities. Periods of drought, of cold winds, of exceptionally dull and humid weather, of over-bearing and exhaustion, may all be precursive, so that it is necessary to be particularly alert at such times. Those who are in charge of labour gangs operating within a plantation should be taught to recognize and report the incidence of disease and to flag each doubtful case with a slender cane and a piece of coloured bunting so that the owner or manager may visit the trees for himself.

Spray Stuffs and Spraying

It is necessary to be prepared and keep all the equipment in good order, with a plentiful supply of spraying materials on hand kept in dry storage under lock and key. Formulae are easily forgotten, so they should be clearly listed and kept in the same place. Special care should be taken of poisonous substances to see that they are kept apart and under lock and key; to see that containers do not get rusty, and disintegrate, or the labels drop off; to see that only responsible people are permitted to use them, i.e., those who know how necessary it is to wash their hands before eating food, to use gloves while mixing, and protective clothing when necessary.

Men using poisonous sprays should never face the wind. Inhalation of a volatile spray is more likely during the heat of the day, just as the absorption of poison through the skin is far more likely when the skin is moist and hot, at a time when operators are likely to take risks because they cannot bear the stuffiness of protective clothing. Dangerous sprays should therefore be used preferably when the air is still and during the cooler hours of the day. Proper supervision must be given to see that no risks are taken.

Should continuous spraying with a poisonous substance be necessary, it would be wise to work in shifts and permit no man to work too long on the actual spraying task. He should be rested if he exhibits symptoms and taken before a medical man at once. Among the symptoms may be a severe headache, a rash, a weakness and shortness of breath, a cold perspiration, blurred sight, shivering and vomiting. Anyone who proves himself allergic must be excused. All these are common-sense precautions that apply to insecticides, perhaps, more than they do to sprays which control diseases, yet it is surprising how seldom sufficient care is taken to guard against accident.

It is necessary to discriminate between the important and the unimportant, between the economic and the uneconomic control of diseases, or pests. Tonic, plus preventive spraying to control a leaf disease, may result in the saving or increase of a hundredweight of clean coffee per acre. This is fine when the coffee is worth £25 per cwt. It is not so good when its value is only £3, since the cost of spraying may then be more than the gain. Moreover, under certain circumstances spraying might be ineffective if the predisposing cause were the extreme exhaustion of the trees on account of over-bearing or a severe drought.

There will be those who prefer dusting to liquid sprays, and though the latter are generally more effective, dusting has its uses especially for some insect pests. It becomes of greater importance when water is scarce.

Spraying in orchards of small trees such as coffee is often most easily accomplished by using batteries of small sprayers rather than the big power sprayers and atomizers used in orchards of large trees. The modern battery sprayers are filled and pressurized at a cross-roads or at a central point and are then strapped on to the backs of workers who can thread their way through the trees and use them as required.

The battery sprayer has been developed from the portable pressure sprayer which incorporated a pump, pressure gauge and safety device. A battery consists of a number of containers each holding about two-and-a-half gallons of fluid under a pressure of two or three atmospheres. The containers are filled and pressurized by a central air-compressing unit usually carried on a

By courtesy of the Plant Pathologist, Coffee Services, Ke

(*a*) Leaves of *Coffea arabica* spotted with the *Hemileia vastatrix* leaf disease

(*b*) The coffee berry disease, *Colletotrichum coffeanum* Noak

By courtesy of the Plant Pathologist, Coffee Services, Kenya

PLATE LVIII

By courtesy of the Plant Pathologist, Coffee Services, Kenya

(*a*) The coffee berry disease, *Colletotrichum coffeanum* Noak

(*b*) The fungus causing the coffee berry disease, *Colletotrichum coffeanum* Noak

By courtesy of the Plant Pathologist, Coffee Services, Kenya

PLATE LIX

trailer, thus a battery is mobile along estate roads. After being filled and made ready for use, a container is unlinked from the compressing unit and carried separately into the field, the worker having no pumping to do to distract his attention and the container having no intricate parts which require maintenance.

As a sprayer's container is emptied he exchanges it for a filled one, and the empty one is refilled, charged with compressed air to the correct pressure and the jet of the nozzle cleaned in readiness for the next man. In such a manner can spraying be done quickly and efficiently over a large area.

Apart from the precautions already mentioned, to avoid delays there should always be a plentiful supply of water placed in readiness at filling centres before spraying has begun; that is if a piped supply is not available. Spare nozzles should be on hand in case of wear, or stubborn blockage; spray liquids made up in readiness should always be strained through coarse muslin when the battery containers are being filled. All equipment should be thoroughly cleansed and washed after the day's work, ready to place in storage or for use the next day.

Low-volume spraying can be effective if the design of the nozzle is based on the pressure range used. For spraying copper fungicides a fan-shaped jet is preferred on tea estates in Ceylon, and a new nozzle is said to have an output of approximately 5 gallons an hour at a pressure of 60 lb. per square inch. Using containers with charges of 2½ gallons, a labourer should be able to spray from 1½ to 2 acres per day.[9]

The Kinds of Diseases

Diseases of plants are caused by fungi, viruses and bacteria. Some are called physiological. Coffee diseases are mainly caused by parasitic fungi which consist of masses of fine hair-like tubes called hyphae. These start from a germinating spore, and may grow into or surround the cells of the plant tissues, drawing their food supplies from the cell sap. The tips of the hyphae are able to secrete a fluid which dissolves the outer cell walls, and the growth of the fungal tissue or mycelium can be very rapid in favourable circumstances. Ultimately, the microscopical plant (for this is what many a fungus is) begins to grow fruiting branches on which spores are borne. These may be of different kinds and produced at different stages of growth, because they may be active spores or resting spores according to the season.

The spores are minute and produced in vast numbers; they are so very light and easily detachable that they can be carried by a gust of wind high into the sky and onward for many miles, or they can be carried by animals and insects, splashed up by rain from the ground, or transported on the clothing of human beings. If they come to rest on a suitable host plant they germinate very soon and begin the cycle of life all over again.

It is to be expected that viruses may soon be found in coffee, if they have not already been discovered. They would cause a yellowing or a chlorosis of the leaf, a vein banding or mottling, and sometimes a distortion of the young growths. Virologists are divided in their opinions as to what a virus is, though the view that it is a living organism is gaining ground. They are of different kinds; they mutate and may be latent, incidental, or malignant, or infectious by touch. A great number show no visible symptoms and appear to do very little harm to their host plants. Others are mild in their attack and the harm

they do is insidious so that the crop is weakened in strength and yield. Some may be malignant, varying in intensity, and killing in their action. Once a virus is present, it may mutate and form a more virulent strain.

The best way to control a virus in orchard crops is to discover a variety resistant to attack. Viruses are seldom carried via the seed from a parent to its progeny, so it is often possible to clean up the disease by planting afresh with seedling stock. Some viruses disappear with heat treatment so that it is possible to place small diseased plants in an incubator and clear them of the disease. Viruses are usually spread by a vector such as sucking bugs, thrips or aphides, and much can be done by eliminating the vector if it is known.

Bacteria are minute specks of organic life which may infect a plant by contact, or through the soil, or be introduced by a vector. They multiply by cell division at a very rapid rate and teem within the living tissues of their host. They mainly cause rots and wilting and are controlled by uprooting and burning infected plants.

A physiological disease is one which appears to be a disease without known cause. It cannot necessarily be induced or inoculated into healthy plants, and eventually many such disorders are found to be caused by trace element deficiencies, or toxic excesses of some elements in the soil. The hot and cold disease of coffee has a physiological origin. In all such cases, attempts must be made to find out what is wrong with a view to eliminating the causes.

The Most Important Diseases

In the author's opinion, some coffee pests are more to be feared than any of the known coffee diseases. Those diseases that have done damage have managed to succeed more on account of the ignorance of man than because of their virulence. If one studies the historical records of coffee diseases one finds numerous reports of new diseases up to the nineteen-thirties, and then the reports dwindle each year, leaving only half-a-dozen diseases that receive somewhat cursory attention today. It is obvious that the dread of diseases has receded; that, in fact, many of the diseases recorded were only of academic interest, without any real threat to coffee.

Experience has shown that diseases can easily be overcome and are rarely troublesome in plantations that are sited in correct environments, and where the coffee is given correct cultural treatments and is healthy in consequence. Even the dreaded *Hemileia* leaf disease can be accepted with equanimity if the soil, the temperatures and the rainfall are right for coffee. If they are not, then special treatments such as shade, moisture conservation and mulching will go a long way to make the disease of little account.

Coffee that is treated in a primitive fashion—grown on unsuitable soils or on eroded, neglected and weedy soils, or planted in environments where there is no hope of obtaining healthy trees—such coffee is bound to be infected and infested with every disease and pest known to man. If diseases are troublesome, then one must conclude that there is something wrong in the environment or in the treatment of the species of coffee being cultivated.

If coffee over-bears and becomes predisposed to disease because of exhaustion, then the cause of the weakness must be discovered. Frequently it will be found to be lack of sufficient moisture, too great a light intensity, lack of

soil shade and temperatures that are too high. Leaf diseases are prevalent on weakened trees, and since they can be checked if the trees are in good health, the root diseases must be rated as most dangerous. Root diseases can be killers and cause gaps, even in healthy plantations, though fortunately they do not appear widespread.

LEAF DISEASE, LEAF SPOT OR LEAF RUST: *Hemileia vastatrix*, B. AND Br.

The fungus appears first as a pale green spot on the leaf, and then orange-yellow pustules break out on the lower surface of the leaf. Each pustule is about one-tenth of a millimetre in diameter and they crowd together in small spots or great blotches, often irregular in shape and sometimes spreading across the whole width of the leaf. When an attack is severe, a whole plantation may appear yellowish at a distance on account of the orange rust spots on the leaves, and the general yellowing of the foliage before severe leaf-shedding sets in.

This leaf disease, which is the most important and dreaded coffee disease in the world, is said to have been taken to Ceylon. It may have been taken in the first instance to Ceylon from Africa where susceptible species of coffee are indigenous, but there are also species of coffee indigenous in Ceylon whence the disease may have been derived.

The first Dutch and British plantings in Ceylon were often placed in a wrong environment, at low altitude, in hot and humid situations. During and after the capture of Ceylon by the British, the original Dutch coffee plantings became overgrown and were abandoned. Later, as the British began to plant coffee, many of the earlier efforts failed because of ignorance, and they also were abandoned, so that there existed many plots of unhealthy, neglected coffee on which a disease could gain a foothold. The disease did not wipe out coffee in Ceylon; it merely appeared and ravaged the plantations at a time when finances were strained on account of low yields due to ignorance of the proper treatment of coffee. Neither was it known how to lessen the effects of the disease or how to control it, so it tipped the scales and made coffee cultivation there uneconomical.

The disease spread somehow to Java and Sumatra, where it encountered the same conditions and did much damage to the Arabian coffee at low altitudes. Arabian coffee survives at higher altitudes in Java today, but the Dutch with admirable persistence turned to importing other species of coffee, which they hoped would prove immune. Some of the robusta and Liberian coffees did prove resistant, so they began hybridizing and grafting on a considerable scale in their efforts to obtain immune, good quality coffee. Hybridizing and grafting did not prove too successful but they had better luck with selected progeny from chosen robusta trees, hence an important robusta industry sprang into being at the lower altitudes.

India was the next to find the disease ravaging coffee plantations of Mysore, and also began to select and plant robusta coffee. A plant of Arabian coffee was ultimately found resistant and was selected and propagated by a planter named Kent, hence the 'Kent's' coffee which is being so extensively planted in East Africa today. The season, the flowering and therefore the fruiting of coffee is more regular in India than it is in many coffee-growing regions elsewhere. Spraying is thus effective and has become a regular practice believed in to this day.

It is to India, therefore, that we must turn for the results of research which may give some basic information about spraying.

To begin with they started to try out various strengths of Bordeaux mixture with and without the use of spreaders. Little advantage was gained by using a mixture stronger than 2 : 2 : 40. Beyond this the use of spreaders incorporated in the spray mixture did not give any appreciable difference either in leaf count or in yield. In comparison with Perenox and other proprietary brands of fungicides, the ordinary 2 : 2 : 40 Bordeaux mixture proved as good, if not superior.

As regards the time of spraying, pre-monsoon spraying gave almost as good results as spraying both before and after the monsoon period. Spraying once after the monsoon did not prove so good. To sum up so far, it was shown over a period of years that the most economic and beneficial procedure was to use a Bordeaux 2 : 2 : 40 mixture without spreaders in one spraying cycle just before the monsoon period.[23] Stronger mixtures and more frequent spraying did not bring any noticeable advantage.

Following this, the results of the same trials were compared for three localities where the conditions of soil and other environmental details might be expected to differ somewhat from each other. Immediately it was found that there were greater differences in leaf retention and yields on account of locality, than on those brought about by the strength and frequency of spraying. This means that the results of spraying may differ according to the locality, and points to the value of extension work from any central research station.

TRIAL AT BALFHONNUR (MYSORE)

THE STRENGTH OF BORDEAUX MIXTURE AND USE OF SPREADER

	Leaf survival percentage observations						*Yield of cherry in lb. per acre*	
Treatment	Sept. 1945	Feb. 1946	Sept. 1946	Feb. 1947	Sept. 1947	Feb. 1948	1947	1948
Bordeaux mixture 2-2-40	30·5	15·6	42·2	13·5	24·8	20·1	787	1699
4-4-40	32·3	18·8	44·8	21·6	27·1	24·0	1013	1866
6-6-10	32·8	23·1	39·4	25·5	26·1	25·9	1052	1679
8-8-10	39·5	25·3	43·8	27·7	26·4	26·8	1079	1742
With spreader Linseed oil at 8 oz. to 40 gl.	33·7	21·6	42·4	22·5	26·0	23·9	977	1696
Without Spreader	33·8	20·3	42·7	21·7	26·1	24·5	988	1795

Note.—No explanation is given of the strikingly better survival of leaves counted during September 1946.

TRIAL AT BALEHONNUR (MYSORE)

BORDEAUX MIXTURE v. PERENOX

LEAF SURVIVAL COUNTS

Treatment Two sprays a year	*Date of observations*				*Mean*
	Sept.–Oct. 1946	*Feb.–March 1947*	*Sept.–Oct. 1947*	*Feb.–March 1948*	
Bordeaux. 2–2–40	24·4	19·1	35·6	17·8	24·2
Perenox					
1 lb. : 40 gl.	23·8	20·8	36·1	14·8	23·9
¾ lb. : 40 gl.	21·1	17·6	32·2	16·0	21·7
½ lb. : 40 gl.	24·0	18·2	30·2	14·7	21·8

Information provided from other sources indicates that Perenox at the correct strength gives equal control without additional expense. If a local trial proved this to be correct, then Perenox would be simpler to use.

TRIAL AT BALEHONNUR (MYSORE)

TIME, STRENGTH AND LOCALITY

Treatment	*Mean effective percentage of leaf survival*		*Yield of cherry in lb. per acre*
	Sept.–Oct. 1948	*Feb.–March 1949*	*1948–49*
Pre-monsoon spray	26·6	18·06	943
Pre- and post-monsoon	26·6	18·98	860
Post-monsoon	12·2	18·44	737
Bordeaux mixture: 4–4–40	22·7	18·62	801
2–2–40	20·8	18·27	893
Locality 1.	25·4	19·46	1175
2.	19·2	13·90	818
3.	20·7	22·12	548

The leaf disease was present to a severe extent in British East Africa in the early nineteen-hundreds, and was particularly prevalent on the var. *arabica* Arabian coffee, then known as the 'Nyasa' strain, in the more humid areas of Uganda. One might say that it helped to cause the abandonment of big-scale Arabian coffee cultivation in areas adjacent to the lake, though severe infestations of *Antestia* bug in conjunction with the leaf disease and the exhaustion brought about by over-bearing were the real causes of failure, the bug being far more upsetting than the leaf disease which could have been borne.

And so, robusta coffee was planted widespread instead of Arabian coffee in

the warmer regions of Uganda, chiefly because the *Antestia* bug did not attack the robusta coffee. Thomas[24] states that individual trees of both Arabian and robusta coffees show varying susceptibility or resistance to the leaf disease. Some of the wild robusta plants in the forests, he says, exhibit mild attacks of leaf disease.

Bourbon coffee became renowned in East Africa for its predisposition to disease. The bourbon variety in East Africa is weak in stamina in comparison with other varieties, whereas in Central America it is so strong as to make one believe there must be different strains, and that the East African one is inferior to that in the Western Hemisphere. One must remember, however, that the climate of East Africa is much drier and often short of sufficient rainfall for this species of coffee.

It is when Arabian coffee suffers drought, or when it suffers weakness on account of over-bearing in an environment that is too warm, too open to intense sunlight, or too dry, that the leaf disease *Hemileia vastatrix* becomes aggressive and so damaging. It causes severe leaf fall at a time when the trees are already weak, and this results in die-back beginning before the crop is fully ripe, leading to loss of crop, empty ill-nourished cherry, and loss of the middle branches of the trees.

Shaded coffee in moister regions appears to throw off an attack, and coffee in temperate high-altitude regions where the soil is fertile and the rainfall not less than eighty inches per annum hardly seems to suffer at all.

In Uganda, the disease flourished during the rains when the crop was swelling on the trees. The lower branches were the first and the worst affected in the beginning, as though the spores had been splashed up from the soil. Later, of course, the whole of the leafage became covered with the spots, with the mealy dusty spores so easily spread around. 'Kent's' coffee has proved outstandingly resistant, growing healthily by comparison with other varieties of Arabian coffee overwhelmed by the disease. Whenever coffee is planted on a light sandy soil it seems more prone to attack. Another predisposing factor is the presence of noxious grasses of the couch variety.

It is curious that the disease did not appear in southern Tanganyika until the middle nineteen-thirties. Nor did it occur in Nyasaland when the industry began and failed for other reasons. It does not appear to be present on the west coast of Africa, and it is certainly absent at the time of writing in all the countries of the Western Hemisphere.

Modern methods of planting, shading, and mulching, together with the choice of better land and its protection from erosion, also the selection of the 'Kent's' variety of Arabian coffee and the multiple-stem method of pruning at lower altitudes, have all done much to protect plantations from severe attack and alleviate conditions during drought. Planters in the British Commonwealth have learnt to bear with the leaf disease and treat it as of no account. Improved methods of cultivation are more important and have done more to avoid severe attacks of leaf disease than all the spraying in the world. Indeed, some people are beginning to wonder whether Arabian coffee could not now be replanted successfully and without danger in countries such as Ceylon and Nyasaland where the crop originally failed. The author is of the opinion that it could.

Hansford has remarked[24] that at higher altitudes, Arabian coffee grows more slowly and takes longer before it bears a sizeable crop. He says that it is quite possible that the slower development of the trees enables them to

become established with a good root system (and stronger branching of course) before crop production becomes a drain on their strength.

Wherever conditions are conducive to severe attack, it is not considered profitable to spray, in normal times when coffee prices are moderate. It is far better to alter the conditions or to grow a resistant variety; to mulch, shade and irrigate, and as a last resort to strip and thin out the crop. It is easy to talk of thinning the crop, but stripping must be done at the right time to be of any use at all, *before the fruit has swollen to more than half-size.* The task of thinning, i.e., stripping a proportion of fruit on a sizeable estate, is considerable and costly, and careless handling may do a great deal of damage to the trees. It is easy to strip on small experimental plots where the cost is rarely considered.

Preventive spraying against a disease of this kind may be economic only in those regions where, on account of steadily alternating seasons, the trees flower, fruit, and flush new leaves which need protection, only once each year.

Experiments at the Lyamungu Research Station confirmed the Indian results, e.g., that a Bordeaux mixture finely sprayed on the leaves proved sufficiently retentive without spreaders, and was often more efficacious and less costly than several proprietary brands of fungicide mixtures.[20]

COUNTS OF LEAF FALL, LYAMUNGU

Treatment	*Test 1 Aug. to Dec.*	*Test 2*
Control 1	14,175	6,465
,, 2	—	7,125
Bordeaux 1%	6,143	1,659
Bordeaux 5%	6,909	—
Copper hydroxide ...	12,616	3,827

In all these experiments with copper sprays and counts of leaf fall, one must remember that a copper spray has been shown to have a tonic effect. This tends to delay the yellowing of the leaves on account of physiological causes and thus their natural fall, masking to some extent the effect of the spray substance on the incidence of disease.

Bordeaux mixture is made up of copper sulphate, quick lime, and water, according to the strengths desired. A good standard mixture is the 5 : 5 : 50, i.e., 5 lb. copper sulphate, 5 lb. lime, and 50 gallons of water. For controlling the leaf disease of coffee, however, a 2 : 2 : 40, i.e., a ½ per cent mixture is the strength advocated.

For coffee leaf disease, 2 lb. of copper sulphate should first be dissolved in 20 gallons of water in a wooden container. The lime should be slaked and mixed with some of the remaining water to form a thick creamy paste before it is made up to 20 gallons with the remainder of the water. We now have two solutions of copper and lime, and if the copper has been dissolved in hot water it should be allowed to cool. The lime used should be of the best quality and as freshly burnt as possible.

When ready to begin spraying, pour equal quantities of the two liquids together, after stirring, so that they pass through a strainer tied across the top of a clean wooden barrel or similar container. The two streams should mix together as they are poured to obtain a suspension that will last while the spraying is being done.

In fact, when widespread spraying is being done it is convenient to make up concentrated mixtures and dilute them as requisite when pouring them together.

An alternative ½ per cent carbide Bordeaux mixture may be made in a similar way using 2½ lb. copper sulphate, 15 oz. calcium carbide, and 50 gallons of water.

An adhesive spreader for use during the wet weather can be made by dissolving 1 lb. washing soda in 1 gallon of boiling water. Then add 2 lb. of resin and boil the mixture for another hour, stirring all the while. When the mixture is cool it may be added to about 30 gallons of Bordeaux mixture. It will generally be found, however, that Bordeaux mixture is sufficiently persistent without the use of a spreader.

Burgundy mixture may be substituted for Bordeaux mixture whenever lime is unobtainable. A solution of washing soda is used instead of the lime water, and the method of preparation is the same. A good standard mixture is 5 lb. copper sulphate, 6¼ lb. of washing soda and 50 gallons of water, but for the coffee leaf disease it is sufficient to use a ½ per cent mixture by mixing 2 lb. copper sulphate with 2½ lb. washing soda and 40 gallons of water.

Burgundy mixture is a little more expensive than Bordeaux mixture but it is more easily prepared and it is said to adhere better and is less likely to clog the nozzles of the sprayers. A concentrated solution should not be mixed and then diluted as is done with the two ingredients of Bordeaux.

Of recent years it has been found that Bordeaux sprays can be effective at much lower concentrations, and it is stated[18] that ¼ per cent sprays, i.e., half the amounts of the ingredients in the same amounts of water would probably be only slightly less effective. For tonic sprayings, higher concentrations are required and it is then only necessary to splash the leaves; for disease control it is necessary to wet thoroughly both surfaces of the leaves. In Kenya a pre-rain spray is given for *Hemileia* disease and a post-rain spray as a tonic.

Spraying should mostly be carried out as a preventive, for it is of little use as a cure when once the disease is widespread. The object is to cover every part of each leaf with a fine spray, so that the deposit inhibits the germination of spores which subsequently fall on the leaves. A spraying given towards the end of a dry season before the young growths develop, may save the infection beginning on the older leaves from which the younger ones in turn would be infected. Towards the end of a dry spell most of the diseased leaves of the previous season will have fallen.

Routine spraying for leaf disease may not be economic or necessary if the climatic conditions are carefully watched as the rainy season approaches, except in low-altitude estates which are always liable to attack.[18] If a few scattered leaf rust spots are present and the onset of the rains is marked by a showery period, followed by warm, sunny, humid days, then spraying should be done during this break in the rains, especially on blocks of coffee likely to bear heavily. If the rains set in and continue, the leaf disease may not be too bad.

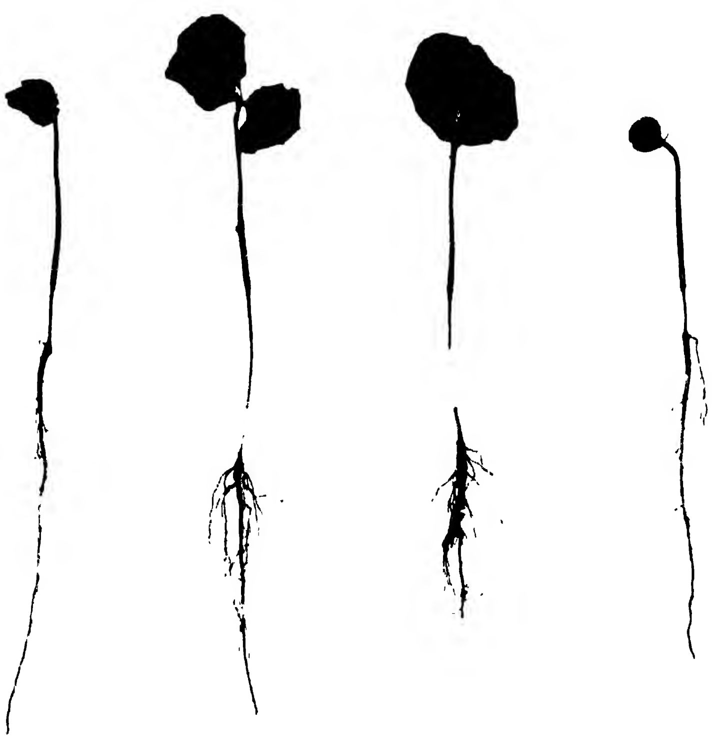
Other Leaf Diseases

There are several other leaf diseases of note, and perhaps the leaf rust disease of the West Coast of Africa should be mentioned. This was first named *Uredo coffeicola* but was ultimately renamed and listed as another

By courtesy of the Plant Pathologist, Coffee Services, Kenya

(*a*) Brown eye-spot disease Cercospera coffeicola B & Ckl. on leaf of *Coffea arabica*, Harar strain.

(*b*) Coffee seedling disease, *Rhizoctonia solani* Note the shrinkage of the stem-part affected



By courtesy of the Plant Pathologist, Coffee Services, Kenya

PLATE LX

By courtesy of the Plant Pathologist, Coffee Services, Keny

The warty disease of coffee, *Botrytis* sp

PLATE LXI

species of *Hemileia*, to wit the *Hemileia coffeicola*. The disease was first found in 1933–34 as a small outbreak in the French Cameroons and was later named a *Hemileia* by Maublanc and Roger. The new rust disease differs from the other in several ways, and tends to cover the whole underside of the leaves with a thick dust of spores. The branches near the ground are the worst affected and in severe cases the disease causes complete defoliation. The authors[11] state that the affected trees grew in localities generally unsuited to coffee, or in regions where the wet season had been prolonged excessively. By 1937 it was reported to be spreading rapidly eastwards.

The American leaf spot disease, *Stilbella (Omphalia) flavida* has been present for many years in Central American and South American countries, and also in the West Indies. According to repute it has been the most important disease in Guatemala, Mexico, Colombia, Costa Rica and Peru[1, 15] and it has caused heavy losses on both Arabian and robusta coffee in Trinidad and Jamaica.[5] The fungus causes large spreading brown spots on the leaves, often near the tips. It attacks the young berries which immediately turn black but are seldom shed, and the fungus develops more slowly on ripening fruit. It is apparently fostered and invited by neglect, weeds, prolonged atmospheric humidity and a damp near-waterlogged soil. It is not considered to be as dangerous as *Hemileia vastatrix* because it can often be avoided by improving cultural methods and by choice of the right environment.

A disease named *Phyllosticta coffeicola* has been troublesome at Kisenyi in the Belgian Congo. This causes irregular pale-brown spots on the leaves, covered with innumerable black pycnidia. It is stated to be prevalent only on weedy plots of coffee.[21] Coffee leaves in Eritrea have been reported attacked by another leaf spot disease diagnosed as *Sphaerella* (*mycosphaerella*) *coffeicola.*

COFFEE BERRY DISEASE, BROWN BLIGHT, *Colletotrichum coffeanum* Noack

The fungus is known elsewhere, e.g., in Ceylon, as *Glaeosporium coffeanum*, and the perfect stage as *Glomerella cingulata* (Stonem) Spauld et V. Schr. It exhibits variation in form and appears to be present on most parts of the coffee tree in a latent and a saprophytic manner, even on dead tissue. When the environment is such as to encourage a change, and a part of the plant is susceptible because of other causes, the fungus appears capable of changing its form and causing an aggressive or mildly aggressive disease.

COFFEE BERRY DISEASE. A FORM OF *Colletotrichum coffeanum* Noack

Coffee berry disease has been found to be aggressive and of great importance at the higher altitudes of Kenya and the Belgian Congo. The disease was first recorded in Kenya in 1922 when the attack was sudden, and during the first years of the disease it appeared to be much more virulent than it is nowadays in the same areas. It changed prosperous coffee farms into liabilities within a single year[19] and caused the abandonment of coffee growing in some regions above an altitude of 5,800 ft. It was reported from the Kivu district of the Belgian Congo in 1938.

More recently the losses have not been so great and have rarely exceeded 2½ per cent, because many of the estates so badly affected in the 1922–35 period are no longer in production. Most of them are said to have been too

high for successful coffee growing, and factors such as hail, low yields, shy bearing and berry fall accountable to other causes, were contributory to their failure.[19] In retrospect the scare loses significance, since the coffee grown in more suitable environments is either not affected at all or is only mildly attacked when rare and wet periods predispose the young berries to the disease.

It seems that a rather peculiar form of the well-known *Colletotrichum coffeanum* is responsible for the coffee berry disease, and that this form attacks the berries only at certain times, when the predisposing conditions are present. According to Rayner[16] he found that fungi of this species, and also species of other genera, were abundantly present on all apparently healthy tissues of the coffee he examined during a small outbreak at Nyeri. In a few cases the special form associated with coffee berry disease was found in leaf tissues, and further observation in relation to what is known as 'weak spots' on coffee leaves confirmed the ubiquitous nature of what are termed latent infections. Investigations in the Congo were also confirmatory.

A careful search for the berry disease form of the fungus was carried out in 1941 in various other parts of the plant, both living and dead, but in no case could it be isolated, though the disease made its appearance in the field very soon afterwards. It was found that each part of the plant tends to have its own form of *Colletotrichum coffeanum*, and that a graduated morphologic series can be made, beginning with those found in the dead tissues of the bark and terminating with the actively parasitic berry disease form.

It is thought that the chemical constitution of the green berry in the affected regions of country is possibly such that a very mild parasitic fungus, capable of invading the superficial tissues and behaving as a 'latent infection', and not developing further until the tissues die, becomes actively aggressive and parasitic on young green berries, and that this consequent change in activity is on account of a change of form.[16] It is thought likely that this change of form takes place only at cold temperatures along with wet and misty conditions when the predisposing factors are all in correlation.

The disease attacks the green berries at any stage of their development, causing a dark brown rot which usually penetrates into the interior and destroys the beans. Eventually the whole berry dries out and looks like dried cherry coffee, or 'mbuni' as it is called in East Africa. The first lesion may occur at one side of a berry, where a slightly sunken dark brown spot rapidly enlarges; or there may be a number of lesions which quickly coalesce to form irregular sunken areas. Quite often the base of the berry and the top of the fruit stalk are the first involved.

The surface of these lesions develops minute, slightly projecting punctules which may be darker or lighter than the surrounding tissue. These are the fruit bodies (*acervuli*), and under moist conditions they may develop masses of pinkish spores. Dry weather will halt the progress of the disease so that only the skin of the berry is affected. In such a case the lesion takes on an ash-grey colour except where it is ringed by a dark-brown edge. The grey area becomes dotted with dark acervuli, and lesions of this type have been called 'scab'.[16]

Diseased berries may be distinguished from those affected by die-back because they appear anywhere on the plant, and the disease is associated with coffee otherwise in good health. Dried berries caused by die-back occur near the tips of the branches and progressively towards the centre of the tree as the

branch dies-back. It is not impossible, however, for berries with disease to appear among die-back berries. The disease may occur when the crop is light and there are no signs of over-bearing.

Other conditions which may be mistaken for berry disease are the 'Warty disease' caused by a form of *Botrytis cineria* Link., also Berry Moth or Butterfly and Brown Blight. Warty disease is distinguished by pale-coloured wart-like areas scattered over the brown dried cherry, and these are covered with a downy, or mould-like fungal growth. The symptoms of moth or butterfly attack are due to the presence within the berry of grubs which bore holes for their exits. Rayner relates[16] that in culture, especially on prune agar, the berry disease fungus is easily distinguished from other forms of *Colletotrichum* by the greyish-black and abundant aerial hyphae, which bear the spores directly on their branches and not on acervuli or other fruit bodies, as in other forms of *C. coffeanum*. The spores are large (6–33 × 4–8 *u*). They vary much in shape and size from oval, through elliptic, to somewhat irregular clavate forms, and have granular contents. The variability in spore shape is typical of the coffee berry disease fungus, and this character alone is sufficient to distinguish it from other forms. The chlamydospores are formed in short chains; these are very convoluted, and coloured dark brown.

Well-managed estates can be badly affected, though neglect of pruning and weedy conditions help the disease. Many of the estates at the time the disease first appeared were neglected on account of the slump. The general relation with high altitudes has been clearly demonstrated and the association with cold, wet conditions has been confirmed. The disease may become prevalent in hollows, valleys and low situations at high altitude where cold air collects at night. The peak of an attack appears to develop in cold, cloudy weather when there is no sunshine.

Infection studies were carried out in Kenya in 1951.[17] In the first attempt the production of the disease by wounding and inoculation was well marked, but painting with a spore suspension using spores from agar-slope cultures appeared to have little effect.

Treatment	*Berries diseased*
Control	13·3 per cent
Painting	15·9 ,, ,,
Wounding and inoculation ...	80·0 ,, ,,

On a tree with no berry disease, none appeared on the controls or on any part of the tree that was untreated, thus there is evidence that infection may be caused by a spore suspension applied to the unwounded berry.

Unaffected tree

Treatment	*Berries diseased*
Control	Nil
Painting	8·7 per cent
Inoculated and wounded ...	84·8 ,, ,,

In the second attempt, susceptible and resistant trees were treated separately and results gained in accordance with the following table:

Treatment	*Susceptible tree*	*Resistant tree*
Control	44 per cent	—
Wounded berries ...	34 „ „	—
Painted	47 „ „	21 per cent
Wounded plus painted ...	60 „ „	74 „ „

A third experiment concerned inoculation by painting with a spore suspension, and a control in which sterile water was painted on the berries. These tests were combined with leaving the branch bagged for three days and for nine to ten days, thus giving four treatments in all. Each treatment was replicated, and also repeated on (*a*) a tree with no disease at the time, and (*b*) a tree with a bad attack. On the inoculated branches a test for infective power of the inoculation was included by wounding a few extra berries and painting these with the spore suspension.

Coffee berry disease did not appear on any of the tests, except on the wounded berries, during the first fifteen days of the experiment, while coffee berry disease was quiescent in the field. At thirty days, the attack in the field started up again and this also affected the experimental branches. No difference in disease rate could be detected, however, between the controls and the inoculated branches. The lesions on wounded berries remained small until the disease became active in the field, when they expanded and infected the whole berry.

Thus it appears that spores placed on the outside of a berry without wounding, only produce the disease when the environmental conditions are suitable.

As the inoculated branches were maintained within bags at high humidity, it would seem that the required conditions relate to temperature or the physiological state of the tree.[17]

It was originally considered that the disease was one which only affected neglected, unpruned and weedy coffee estates. Later, opinion began to favour the opposite and it was thought that the most vigorous plants were most affected. Tests seemed to show that neglected plots yielded nothing, whereas well-pruned trees yielded four cwt. per acre with an incidence of twenty-eight per cent berry disease. It was concluded that pruning to obtain vigour did not control the disease but only masked its effects by producing a large crop. Manurial experiments with major and minor elements have had no effect on the incidence of the disease yet.

As for control measures, preventive spraying tests have been disappointing and in no case a hundred per cent effective. There have been no outstanding results, and although some degree of control is exercised by most fungicidal sprays, the use of chemicals can hardly be economic until an efficient systemic fungicide is developed. A complete and permanent coverage is otherwise required, and this would be too expensive to maintain.

An inherited resistance is the best method of overcoming the disease. Bronze-tipped forms of Arabian coffee and the Blue Mountain Jamaica strain appeared to offer a definite degree of resistance, and within such strains a further selection might be possible from outstanding trees.

Most strains of coffee appear to be safe from attack in Kenya below the altitude of 5,500 ft. Blue Mountain Jamaica, though not immune, will

generally be resistant up to an altitude of 5,700 ft., thus extending the range of immunity by 200 ft. Even in bourbon coffee there appear to be varying degrees of susceptibility and resistance. The Harrar Abyssinian strain of coffee, though a vigorous grower, appears to be particularly susceptible to the disease.

Rayner[16] advances the theory that the virulent form of the fungus causing berry disease is evolved by the reaction of coffee tissues physiologically suited to attack on the less pathogenic forms of the extremely polymorphic and variable organism.

Conversion of a susceptible plantation to a resistant one by grafting the rootstocks with Blue Mountain scions has been shown to be possible, and results in the production of bearing trees earlier than by replanting with seedlings. In bad high-altitude regions, however, even Blue Mountain coffee may be too severely attacked to produce an economic return. Unfortunately the present strain of Blue Mountain coffee in Kenya is not a very heavy yielder and the quality of the cured bean is somewhat inferior to 'Kent's' or bourbon coffee.[19]

BROWN BLIGHT DISEASE, A FORM OF *Colletotrichum coffeanum* Noack

Brown Blight disease appears to be another form of the *Colletotrichum coffeanum* fungus which attacks the coffee berry when it is ripening in parts of East Africa. It is sometimes found with, or following the coffee berry disease, and the form arises when the environmental conditions and the constitutional character of the trees and their fruit favour its presence.

The disease seems milder and less aggressive than the coffee berry disease and as it occurs when the fruits are fully formed, there is not such a loss of crop. Brown patches appear on the fruits in a cluster and they tend to make the fruit skins shrink on to the inner parchment shells and thus cause trouble during pulping. Since this disease is not so serious and it occurs so late in the season on the fruits alone, it has not been considered economical to try to control it. It, too, must await a systemic fungicide which would be such a boon in controlling diseases of this kind.

It might be possible to confuse this disease with the brown leaf spot and berry blotch disease, with sun scorch or die-back. Indeed, other forms of the same fungus attack the dead tissues such as the bark, old fruit stalks, die-back branches and so on; also the drying tissues of the ripening bark or fruit, in which case the attack may be early enough to prevent the proper ripening of the fruit which is the condition known as 'Brown Blight'. It is only arbitrarily distinguishable from a mild and late attack of coffee berry disease.[19]

BROWN EYE-SPOT AND BERRY BLOTCH. *Cercospora coffeicola.*

This disease is more general. The fungus attacks the leaves and berries of all types of coffee, though the berry form is said to be more common on *Coffea arabica.*[24] The leaf spots are dark brown and usually quite small, no more than three to five millimetres in diameter but sometimes two or three times larger. They later become grey or almost white in the centre and have a reddish-brown zone round the margin. The fungus may attack nursery plants or young plants soon after they have been transplanted in the field, and it has

been known to be severe on the Harrar strain of coffee which appears peculiarly susceptible to fungoid diseases.

The disease will also cause dark blotches on the berries which later turn black and shrink, so that they may fall before they are fully ripe. The diseased tissues of the fruit-skin become dry and hard, making them difficult to pulp. If some are mixed with good ripe cherry they cause imperfect pulping of the whole, so that the beans are nipped by the machine and the value of the product is reduced.

Very seldom does the disease appear serious enough to warrant control measures. It is generally to be found on ill-nourished, unshaded coffee at low altitudes where moisture is deficient in the soil.

WARTY DISEASE, A FORM OF *Botrytis cinerea* Pers.

Warty disease is distinguished by light-coloured wart-like areas scattered over the dark-brown, dried berry, which is covered with a downy mould-like growth of the fungus. This, again, is not a very serious disease.

Control measures of a chemical nature would not be economical to apply. A well-managed, well-mulched plantation shaded at the lower altitudes is unlikely to be troubled very much. There is a tendency for coffee pickers to leave diseased berries on the tree, and, near the close of the picking season planters often disregard a thin scattering of berries that may not be worthwhile picking. Such remaining berries are likely to carry diseases, and pests of course, from one season to another, so for this reason it is best to pick them all as soon as possible and burn all the diseased material.

'MBUNI', EMPTY CHERRY, DIE-BACK

The yellowing of leaves, leaf fall, and the shrivelling and dying back of the branch tips is a common physiological occurrence when trees are carrying a heavy crop. It is a sign of starvation or thirst, and it is brought about by over-bearing, by light intensity in unshaded coffee, by lack of moisture, weed competition or unhealthy roots. It occurs more frequently at low altitudes in environments that are too warm and too dry.

A severe attack of thrips or other defoliating insects, or damage by borer beetles to the main trunk, or a severe attack of mealy bug at the roots, indeed, anything that weakens a tree to the point of exhaustion and near death, will bring about the die-back of its branches. It is often the middle branches which are carrying crop that are lost, and the die-back usually occurs when the berry is almost full size but before the beans have matured. A number of brown, somewhat shrivelled berries are left adhering to the branch, and if they are examined immediately the die-back takes place, they will be found devoid of fungal attack.

SUN SCORCH

Unshaded coffee during dry hot spells, especially the rows or the sides of the bushes exposed to the afternoon sun, may be found to carry a number of ripening berries with a brown patch on one side. This is again nutritional and physiological. It often occurs when the leaves are yellowing, though die-back need not necessarily occur.

BERRY FALL

The shedding of young berries on a large scale may occur on plantations in a new locality without apparent cause. It may be found that there is an excess or a deficiency of an element in the soil. In some volcanic ash soils which appear fertile enough on the surface, there is an excess of alkaline substances in the subsoil which may cause the yellowing of leaves and berry shedding. A severe drought on the one hand or waterlogging on the other, may be the disturbing factor. The author noticed a severe shedding of young berries during a bad infestation of *Antestia* sucking bugs in Uganda in 1918, and since there had not been shedding at any other time it was presumed that they were the cause. Whenever any strange event of such a nature occurs, the appropriate authorities should be informed immediately.

COFFEE BEAN DISEASE. *Nematospora coryli.*

This disease was first discovered by Dr. G. B. Wallace in Tanganyika. The coffee berries appear quite healthy and grow naturally to full size. The beans, however, show minute punctures and are discoloured and rotten inside. As the beans are infected independently, only one may be affected. The fungus causing the disease is introduced by *Antestia* sucking bugs, so that control measures concern the elimination of the bugs.

DAMPING-OFF DISEASE. *Rhizoctonia bataticola* AND *R. solani*

These two diseases are similar in action and attack young coffee seedlings soon after germination. The plants are attacked, usually at one side just below the ground, so that the tissues rot and the seedlings wilt and die. Although the disease can spread rapidly and do severe damage, it is rarely troublesome in properly sited nursery beds where the watering is not overdone. Nursery beds should not be constructed on or near swampy ground, shade must not be too dense, neither must the soil be kept too moist. Overcrowding also favours the disease, which rarely attacks seedlings that have been properly spaced.

Damping-off disease will also attack cuttings in frames where the air must be kept humid and the compost continually moist. Watering the soil beforehand with Cheshunt compound before the cuttings are inserted has become a routine procedure in East Africa.

RHIZOCTONIA ROOT DISEASE. *Rhizoctonia lamellifera*

This disease will affect a number of plants. It begins on the very fine rootlets of coffee and spreads to the thicker roots and the base of the stem of mature trees. Small black sclerotia are then noticeable in the woody tissues of the main axial roots and the basal portion of the stem, and since the disease is not 'aggressive' it appears on individual trees which may die mysteriously, and be scattered widely in a plantation. Termites may then attack the dead and dying tissues. The trees and their roots should be dug up and carefully burned. The soil should be dug deeply and opened up to the air. A young tree carefully planted in the same place the following year need not necessarily contract the disease.

TOP, OR TIP DIE-BACK *Rhizoctonia* sp.

This disease has been reported from several countries and it became very serious in Java from about 1930 onwards, so that on some estates eighty-five per cent of the trees were being affected. It can be described as a sudden die-back from the tip downwards, and not of the middle branches as in ordinary die-back which is due to exhaustion. It is most serious in over-shaded estates where there is high atmospheric humidity. The control measures exercised have been to prune away the affected tops of the trees below all signs of infection and burn the prunings immediately.

PINK DISEASE. *Corticum salmonicolor.*

This is generally listed as a disease of tea. It has been known to be serious on coffee in one region of Kenya where hailstorms were frequent, or where there was too much shade. It caused damage to the branches of coffee in the Belgian Congo in localities that were very wet but it is rare and unimportant as a coffee disease in the world.

COFFEE CANKER, THE TRUNK AND SHOOT CANKER

The disease, known otherwise as the Sabre-wound disease, is rated as an important one in Colombia, and it is caused by a canker disease, *Ceratostomella (Ceratocystis) fimbriata.* When the disease is severe the bark becomes gnarled and cankered with criss-cross wounds as though it had been stabbed or slashed with a sword, hence it is known in Colombia as the sabre-wound disease. The disease attacks the trunks and the older branch wood and possibly gains an entrance through primary wounds due to some other cause. The control exercised is to prune away and cut away diseased parts, treat the wound with a ten per cent solution of formalin and then apply a Bordeaux paste. Pruning should be minimized on healthy trees and notice taken of any insect pest that might be gnawing or piercing the bark, with a view to its elimination. Where an attack is likely it might be wise to spray the branches with Bordeaux mixture immediately following a severe hailstorm. Every effort should be made to modernize the methods of cultivating coffee in areas subject to attack.

ROOT-COLLAR DISEASE. *Helicobasidium compactum* Boedijn

Coffee is mentioned as being a host plant for this disease when it has been growing near tea gardens in Java. The disease usually envelops the stems of young trees at their collars. The young trees often wilt and die when the weather turns dry after the long rains. It is known in India as violet-root rot, because the velvet mycelium covering the stem and roots is mauve in colour, or a brownish purple.

The disease is said not to be influenced by a wet soil, and there is a strong suspicion that tea, at any rate, is predisposed to attack when the soil is alkaline. Tea and coffee both prefer a soil with a *p*H value of about 4·5. Should the disease appear on coffee it would be wise to check the *p*H of the soil, especially in the nursery.

ROOT ROT. *Armillaria mellea.*

This disease is responsible for severe damage to many orchard crops. It is widely distributed, and is a common saprophyte in forest soils where it lives on dead stumps and roots. Under natural conditions it attacks weak and dying roots and stumps where it obtains a hold; it singles out among the neighbouring growths those that are particularly susceptible, and to these it spreads and becomes aggressive.

Infection in tea and coffee estates is generally derived from forest tree stumps that have been left in the planted clearing, or from tea, coffee or citrus trees that have been stumped in preparation for replanting. The fungus lives on these dead stumps and attacks living roots which come in contact with the dead roots of its host below the ground, or by means of its root-like strands of mycelium known as rhizomorphs which meander about in the soil surrounding its position.

Symptoms are often sudden, i.e., the wilting and yellowing of foliage followed by the death of the tree. It often happens that a group of trees are affected at the same time. Longitudinal cracks in the bark of the larger roots and the base of the stem will be found, sometimes extending above ground level. These are filled and surrounded with brown or black rhizomorphs and fungal tissue, which may be formed in a frill, and a thick layer of white mycelium will be found between the bark and the wood of the roots, smelling strongly of fresh mushrooms.

Every owner of an orchard crop such as coffee should be on the lookout for this disease so that he may quickly diagnose the cause. It is imperative to take action to prevent the disease spreading to neighbouring trees.

If forest trees are felled prior to planting an estate, it is an advantage to ring-bark them a year beforehand so that they die in advance. By ring-barking a forest tree the finer roots are quickly starved to death and fairly soon consumed by harmless saprophytic fungi. Then, when the trees are felled, the stumps should be uprooted and burned together with as many of the smaller pieces of dead root as can be gathered up. Similarly, when coffee trees or shade trees are stumped, the roots should be carefully dug out of the soil.

Should a coffee tree, or a group of trees, die of this disease, the roots should be dug out as carefully as possible and thoroughly burnt. Neighbouring trees must be suspect and treated as infected, and a search made for rhizomorphs in the soil. An isolation trench at least 3 ft. deep by 1 ft. wide should be dug to surround the outer perimeter of the infected trees to include the whole area considered to be suspect, and the soil from the trench should be thrown on the inside of the circle thus formed. The holes from which the soil has been dug should be left open and aired for about six months before replanting, or a thick cover crop of *Crotalaria anaegyroides* or of *Tephrosia candida* sown over the infected area may create conditions in the soil unfavourable to the existence of live mycelium.

OTHER ROOT ROTS

There are a great many fungi which cause root rots of one kind or another and many of them are cosmopolitan in the crops they attack. They may use wild plants as hosts, so that a disease may originate in wild growths

on the boundary of an estate. Some are very troublesome among interplanted crops, so that a root-rot disease which is a severe pest of rubber may be found to attack coffee interplanted in rubber. Others attack shade trees and spread from them to the coffee, while cover crops such as Crotalaria or Tephrosia may also act as hosts and be attacked by the disease at the same time.

Root rots are often rated as one of the chief diseases of coffee. Though they do not attack coffee wholesale, they may be of such frequent occurrence, and so malignant that they are naturally rated as dangerous. Along with the borer beetles among the insects, root rots are a cause of the gaps in older coffee plantings, and these must be avoided at all costs because of the drop in yield per acre that results.

Undoubtedly root rots are assisted by planting coffee in unsuitable environments, and also by neglect of the orchard or lack of knowledge of how to give coffee the correct treatment. Root rots are very rare in East Africa nowadays because the methods of cultivating coffee have been modernized by research. Even the peasant growers of the three territories have been taught so well, and have been so amenable to instruction that their smaller plots of coffee are generally in satisfactory order.

There is the fungus commonly known as *Fomes lignosus*, or the 'white root rot'. It is said to be assisted by unfavourable atmospheric conditions and is known chiefly as a disease of rubber trees. The roots of the tree attacked bear yellowish-white strands of mycelium. The disease attacks coffee chiefly when it is inter-planted in rubber, but it has caused damage to coffee in the Belgian Congo and in several countries where rubber is not grown on the same site. The *Leucaena glauca* shade tree is said to resist the disease.

Fomes lamaoensis, known as the 'brown root rot' of rubber, has been said by Mayne of India to be the most common cause of root rot in Mysore. It is said to be widespread in Java and to occur in Malaya and several other countries. It was originally described in the Lamao region of Luzon in the Philippines. The disease is characterized by the manner in which the roots are encrusted with soil particles held to them by the fungus. *Phellinus lamoensis* syn. *Fomes noxius* are names also given to a brown root rot which attacks coffee in Sumatra and India. The disease often attacks *Leucaena glauca* shade trees whence it spreads to the coffee bushes.

Pellicularia (*Corticum*) *koleroga* Cooke, commonly known as *Corticum koleroga* or the 'Thread Blight' of coffee, is widely known in India, Surinam, Venezuela, Mexico, Trinidad and elsewhere. It is said to be very prevalent in Mexico and to assume severity among neglected Arabian coffee plots in Trinidad.

Next we have a genus of considerable importance which causes the 'black root rots'. These are *Rosellinia* sp. of which *R. bunodes* B. and Br., appears to be the most widespread. It has killed a number of coffee trees in Java where the *Hevea* rubber trees and *Leucaena glauca* shade are said to be chiefly affected and to act as the original centres of infection. The green manure crops used are also said to be susceptible. *R. bunodes* is essentially a collar-rot fungus and it kills a tree by girdling it with the rot. The collar and upper parts of the tap root are rotted away while the lateral and smaller roots remain healthy. It can be distinguished easily from *Fomes lamaoensis* because of the gnawed appearance of the bark where the rot occurs. *Rosellinia necatrix* is

listed as the chief root rot in Brazil, while *R. pepo* is mentioned in New Guinea.

A second form of black root rot that spreads to coffee, usually from Hevea rubber, is known as *Xylaria thwaitesii.*

With the occurrence of all these root rots, it is necessary, of course, to remove the predisposing factors and sources of infection if possible. Where coffee is inter-planted as a catchcrop in a *Hevea* rubber plantation, then the coffee must take second place. Action will be taken against the disease to save the rubber. There are definite reports that the shade tree *Leucaena glauca* is sometimes the primary victim of the fungi. When this is so, it would seem sensible to find a shade tree less susceptible.

It may help to lessen the incidence of these diseases if shade is reduced to the minimum required, and windbreaks thinned to permit a free movement of air. Better drainage may be desirable and a thin alternate-row mulch of wilted cut grass, rather than a rank growth of some cover crop which might create a sour soil.

A watch should be kept for infected trees and immediate action taken to eliminate the potential cause of a widespread infection. Diseased trees should be uprooted and burnt long before they are dead, including every piece of the thicker roots which can be found in the soil. Beyond the root range of diseased or suspected trees a trench should be dug and the soil thrown inwards on to the isolated circle of soil. The site of the diseased tree should then be deeply dug and aerated. If this is done carefully, it may be possible to plant again and rear a healthy tree in the same place about a year later, provided the shade is reduced sufficiently to allow the young tree enough light.

Bacterial Diseases

SIEVE TUBE OR PHLOEM NECROSIS

Apart from galls on the roots of coffee which were discovered in the Belgian Congo to be associated with bacteria, and the suspicion that bacteria are also associated in some way with the domatia which form in the vein angles of some species and forms of coffee (a matter which requires more investigation) there is only one serious disease attributed to bacteria.

It is known as 'Phloem necrosis', for which a flagellate named as *Phytomonas* (*Leptomonas*) *leptovasorum* is responsible, although W. J. Dowson, in his *Manual of Bacterial Plant Diseases*, states that *Phytomonas* has been rejected by taxonomists.

Though the phloem necrosis disease may be found attacking all the economic species of coffee, it has been coupled with the Liberian species most of all, and it has caused serious losses both in Surinam and British Guiana. Some say it is spread from forest trees by Coccid insects which introduce the disease when they suck the sap from the phloem tissues. It is thought that the so-called 'red disease' of Brazil is caused by the same organism.

The disease has been known in Surinam since about the very early nineteen-twenties, and the percentage of loss varies from about 1 to 3 per cent of the trees to a maximum of from 10 to 25 per cent when the disease is severe. The leaves of mature healthy trees suddenly shrivel and die, and they are held for some considerable time before they are shed. A microscopical examination

discovers that the sieve tubes in the phloem tissues are gummed up and brownish red in colour. In any meristem tissue that is not visually affected, the dividing cells are found to contain numerous flagellates.

Trees that are diseased usually die. They should be removed at once and burnt nearby as soon as the symptoms are recognized. A thorough investigation by local research officers might discover the vector and means of checking the carry and spread of the disease.

Physiological Diseases

DIE-BACK

Die-back is undoubtedly physiological, and caused by exhaustion after a tree has overborne its strength, or by root-starvation when trees have been defoliated by a true disease or pest. Drought will also cause die-back because the leaves turn yellow and lose their powers of assimilation if the moisture content of the subsoil drops to near wilting-point.

This form of die-back is easily recognizable, since the branches begin to shrivel at their tips. The leaves shrivel in turn as the die-back progresses, and the dying portion turns brown, deepening to a dark brown and almost black. Any immature berries also dry up, turn brown and are held on the branches. Usually the middle branches of a tree are the worst affected because they are the ones that have borne most crop. They may die right back to the main stem and be lost, or if the tree is being assisted to recover, the last internodes may remain alive, and from these new laterals may grow. A tree is rendered very ragged in appearance and may take two years before it will bear another good crop, when, if the environment or the treatment is at fault, the whole cycle of events is repeated.

HOT AND COLD DISEASE

This is again physiological and due to extremes of temperature, especially the cold night temperatures at high altitudes. It may occur when a cold kabatic wind flows down a valley and passes over the tops of the coffee bushes.

The symptoms are a curling and shrivelling of the leaves and green shoot tips, followed by a blackening of the affected parts. In truth, the younger parts of the trees have been scorched by the cold, following warm sunshine during the hours of daylight. It is at high and cold altitudes, or in temperate latitudes where coffee is not shaded, that this damage occurs, and when cold temperatures are likely to harm the trees, a light shade may be beneficial and protective. Kabatic winds may be turned aside by barriers such as high hedges, and ordinary winds by wind breaks.

It is said that other symptoms are slow growth, even in the seedling stage, and a stunted bushy growth as the trees grow older. Surely, however, these symptoms must indicate that the environment is too cold, and that coffee cultivation had better be abandoned. It happens sometimes that such symptoms occur in coffee planted in valleys and hollows where cold air collects at night, whereas higher on the surrounding slopes the trees are not affected.

LEAF YELLOWING AND BERRY SHEDDING

If there are no disease organisms or pests present, then leaf yellowing is usually brought about by high light intensity coupled with a lack of sufficient moisture, or with trace element deficiencies or excesses. Berry shedding can take place on account of similar physiological causes. It must be considered symptomatic of a serious state of affairs, because it is unnatural for a tree to shed its fruit until it is in a state of extreme unbalance and near death.

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Chapter XIV

THE PESTS OF COFFEE

The Classification of Pests

THE word 'pests' covers a wide field. A pest may be an insect in some, or in all stages of its life history, a tiny mite or a spider, a nematode (eelworm), a slug, a four-footed animal or a noxious weed. Insect pests may be roughly classified in various ways irrespective of their true family grouping, e.g., as sucking insects, biting insects and boring insects. One might also classify them according to the parts of the plant they affect, or list them in accordance with their importance to the coffee-production industry.

Natural Controls

Unlike diseases—if one may exclude microbiological matters, which do not, as far as we know, affect any of the coffee diseases very much—insect pests usually have parasites which help to keep them under control. Hence, when we begin to employ methods to overcome an insect pest, we must endeavour to avoid harming the helpful parasites. Not only must we not depress the parasites of the pest in question, but also those of other minor pests which might be present; for, in the absence of their parasites, they, too, may assume alarming proportions and be worse than the first pest we attempted to overcome.

The whole matter of insect pest control is complicated and dangerous, and especially is this the case in a country where coffee is indigenous in the vicinity. The coffee is then within Nature's balance. It has its local pests and diseases which, on account of natural controls, do not affect it very much until man upsets the balance. He does this when he takes coffee out of its natural habitat and cultivates it in large homogeneous monocultures, especially when its new environmental conditions are not quite satisfactory, and also when, by carelessness, he introduces some foreign pest.

At times local pests break out and become a severe nuisance because Nature's controls have temporarily been upset, either because the parasites have been inhibited, or the pest itself encouraged by some cataclysmic disturbance in the environment, such as a drought, or a long spell of dull, wet and cold weather.

Care in the Use of Insecticides

A new and powerful insecticide can itself be a cataclysmic disturbance unless it is used with care and foresight, hence the Kenya Authorities' policy of proceeding with great care. It is far better if a natural control can be established by introducing new parasites to the pest; far better to bear with a small percentage of loss rather than to overcome a pest with one spray, only to find that another, and yet another, have grown to be menaces and require a second and a third treatment. One has only to speak to a fruit grower in

England to discover that an ever-increasing percentage of his profits is lost on cycle after cycle of spraying against one pest or another.

The indiscriminate use of D.D.T. against *Antestia* bug might lead to a build-up of mealy bug, green scale, or the lace wing coffee bug, merely because their parasites have been destroyed, or severely reduced in numbers.

When considering whether a chemical compound should be used in combating insect pests we must consider its toxicity to all the insects in the field. It must kill a high percentage of the pest, but it must be innocuous to foliage and product, also harmless to beneficial insects in so far as this is possible, and to the health of the operators and consuming public.

It is difficult to account for the intensification of pest control problems in mature countries. We have to bear in mind, in correlation with our human efforts at control, the influence of spray treatments on the natural enemies of insects, the development of strains of insects resistant to the insecticides used, and the profound effect of weather conditions which ordinarily affect the insect populations. Even where an insecticide is more than ever effective against some pest, its ultimate effect may be an increase in the prevalence of the pest so that an occasional local attack becomes a perennial problem.

Spraying should supplement Nature's controls and not work at cross purposes with the natural enemies of a pest.[26] All endeavours and all research should be devoted to this end.

Sanitation and Plant Resistance

If an insect pest pupates in any of the material on the estate, we should endeavour to clean it up. A well-managed estate is in a sanitary condition, a neglected one is dirty. Take, for instance, the coffee bean borer which is particularly troublesome with robusta coffee. The coffee bushes grow to a considerable size and not all the berry can be picked or shaken down during the time it is harvested. Dried-up fruits remain on the tree or on the ground, to become breeding material for a carry-over to the next season.

It would surely be wise to keep the bushes and their surroundings clean of dried berry for the greater part of the year, yet, in view of the previous paragraphs, it might be better to test the emergence of the pest. We might find parasites emerge as well, for they also need a bridge to carry them over to the following season.

For one reason or another certain varieties of a crop show resistance to some of the insect pests, more especially when they are cultivated in the correct environment. 'Kent's' coffee is a case in point, for the author has seen odd plants of 'Kent's' coffee standing among bourbon coffee bushes infested with green-scale, yet the 'Kent's' coffee remained clean. The *Antestia* bug appears to prefer Arabian coffee and does not trouble robusta coffee very much, possibly because the green berries of robusta coffee are not so juicy and sweet. The coffee-bean borer seems to prefer the robusta coffee berry to Arabian berries for the reverse reason, though there may be other reasons, such as shade, and a greater carry-over in the dropped fruit.

Major Insect Pests

If one searches through the volumes of the extracts of Entomology applied to Agriculture, working forward to the present day, a whole host of pests are

mentioned which attack coffee in one country or another. Records of most of them, however, gradually dwindle after a time until there is regular mention from year to year of less than a dozen pests. Of these several occur in only one or two regions, others are almost world-wide and some occur everywhere.

Most pests which are wholesale in their attack and on occasion do widespread damage, such as *Antestia* and Thrips, are dangerous only in regions where temperatures are sometimes too high, no shade is provided, and where the rainfall is short and erratic. Curiously enough these are fairly easy to control, and cultural conditions can so alter the environment as to make their appearance less likely. A planter may have himself largely to blame nowadays if trees are lost through these agencies.

Mealy bugs and scales are more persistent. One or more species occur in most countries, but these, also, can be controlled. They neither attack in such a wholesale fashion if their presence is resisted, nor are they responsible for the death of coffee trees to any great extent.

Of all pests, the borer beetles are most to be feared. The bean borer now occurs in many of the chief coffee-producing countries and is responsible for considerable damage to and loss of crop. Branch-boring beetles cause widespread damage on the west coast of Africa and elsewhere. Stem-boring beetles of one kind or another are found in every country and are the most dangerous pests to be found.

There is no direct method of control against the stem borers. Each of the thousands of trees on a plantation must be watched for its appearance and hidden depredations. The larvae of the beetle must be hunted individually, for they are responsible for more deaths of old and valuable trees than anything else. Left to themselves when they occur, they can wreck a plantation and cause so many gaps which cannot be filled that the yield per acre becomes uneconomic.

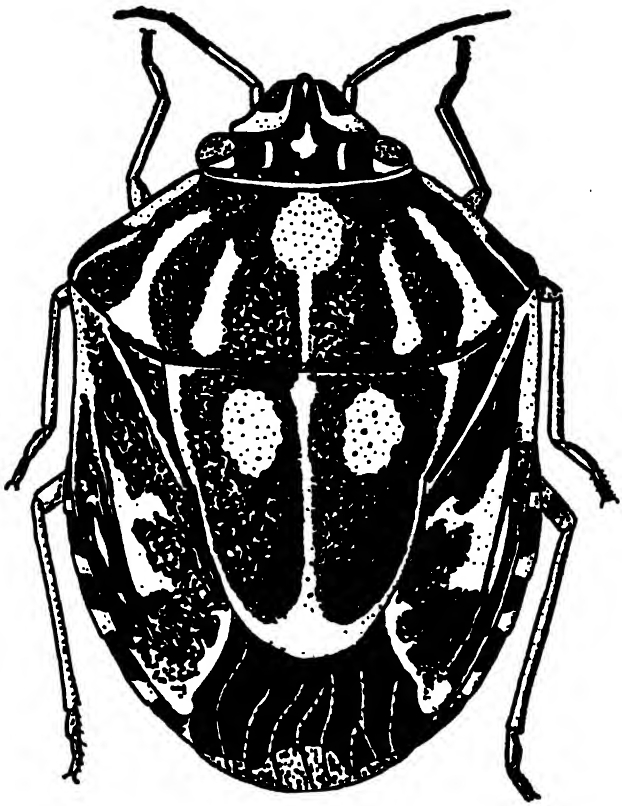
However, well-managed estates of healthy trees are not attacked to anything like the same extent as those which are sited in wrong environments, or are neglected. Four-fifths of potential troubles can be avoided by sound methods of cultivation in a proper environment.

THE VARIEGATED COFFEE BUG

Antestia lineaticollis Stal., and *A. faceta* Germ., formerly known as *A. variegata*. These two bugs, sometimes appearing together but generally separate and very similar in appearance, were at one time considered to be varieties of one species. Wherever they appear they at once become a major pest of Arabian coffee, and it was Hargreaves in Uganda who proved that the two could not be crossed and lay fertile eggs, hence they must be separate species.[28]

In Uganda the bugs were first observed on a plantation near Lake Victoria in 1915 and during the next two years they spread to coffee plantations in several adjoining districts. In 1922 and later years more distant areas were affected, always with disastrous results. The author had his own plantations attacked in 1916 when little was known about how to control the pest, and whereas the leaf rust disease and other troubles had by that time been overcome, the *Antestia* bug became the last straw for many planters. (*See* Fig. 31).

During the seasons when the coffee plantations were bearing good crops of berry, the pest bred with great rapidity and invaded the trees. Since they fly



By courtesy of Mr. W. Victor Harris

FIG. 31.—Coffee bug *Antestia*. 7mm. long.

vigorously during the heat of the day one had only to touch a tree to be surrounded with the insects in flight. Practically 90 per cent of the crop was lost, either because the immature berry was shed, or the mature berry was found to contain empty parchment, or beans so shrivelled as to become useless.

After the crop was harvested the insects attacked the young leaves and growths and especially the young buds, causing a swollen warty appearance followed by multiple growths as though a 'witches'-broom disease' was present. The more the pruning knife was used the more did growth develop at the expense of flower buds.

Attempts have since been made to show that the berry shedding and multiple growth is brought about by other causes, as so they might, but there is no doubt whatever that they occur in conjunction with severe *Antestia* attack and that both can be caused by the constant puncturing and sucking of these bugs.

Hargreaves says,[28] 'the tissues of the coffee seed are soft and spongy until some time during the fourth month of development, and these immature berries are by far the most favoured food of *Antestia* in both young and adult states. The extraction of the highly nutritive food during the sucking of berries leads to the formation of spotted or irregularly shaped beans, or, in the

extreme, to useless, minute, shrivelled remains of beans. The damage is not evident externally, and apparently sound and normal-sized berries may, on cutting them open or after pulping, reveal a total loss of the potential crop.'

'The nearly mature berries are also attacked, but feeding in this case appears to be restricted to the pulp.'

'In the absence of berries the bug flavours flower buds as a source of food, and considerable flower-failure may result from such an attack. Where the preferred food-sources are absent or scarce, succulent young shoots and tender leaves are attacked and serious indirect loss results from the stimulation to precocious growth of secondary and tertiary branches, this causes a matted growth requiring careful and costly pruning before crop will be produced, in addition the internodes are abnormally short. The sucking of very young leaves causes them to be deformed with curly laminae and irregular margins.'

It appears that the bugs breed when the fruit is being borne, and that at other times only adult insects are found upon the trees. In some areas they are responsible for infecting the seeds with bean disease which causes them to rot.

All that the entomologist in Uganda could advise in the early days was hand-picking, also the collection of the egg clusters and hatching these in containers, (*a*) to note the percentage of the parasites, (*b*) to allow the parasites to escape. Planters wasted large sums of money in ludicrous attempts to control the bug by hand-picking—a measure that could never be economic or effective. As for collecting the few eggs a labourer could find during an eight-hour day, this was absurd, as the parasites hatch out, anyway, if they are left alone.

Egg collecting did, however, show that as an attack developed, so did the parasites increase and tend to reduce the number of the bugs. There are several egg-parasites in Uganda, and in the older areas first attacked, the bugs do not now appear so prevalent, possibly because some form of natural control has taken place. Steps have been taken by the Agricultural Department to introduce the parasites into areas where *Antestia* has become established in their absence.

Notley[22] has concluded that on Kilimanjaro Mountain, where a parasite of the adult bug is present, *Antestia* tends to increase in numbers only during the hot, dry weather from November to March. This parasite *Corioxenos* appears to depend upon rather high numbers of *Antestia* to be effective, but a high parasitism is maintained throughout the cold weather in shaded plantations, reaching an average of 40 and 50 per cent.

Antestia does not appear to thrive at high altitudes, where a good deal of misty weather prevails and the rainfall averages show an even spread of eighty inches per annum. It is at the warmer, lower altitudes, and especially on unshaded coffee that the *Antestia* can become such a devastating pest, and build up so quickly.

Notley[23] has shown that an average of only two *Antestia* bugs per coffee tree can cause over 15 per cent damage to the crop irrespective of indirect damage. He states that the planters on Kilimanjaro were endeavouring to keep down the average to no more than one per tree. In Kenya, at first, they made the limit four per tree, and then reduced it to two, because in general practice it is unlikely that planters will spend money on control measures until the damage is appreciable.[10]

Le Pelley recorded that although *Antestia* will feed on leaves, shoots, flower

buds and older berries, large green berry food is essential for the normal length of life and egg production. There is thus a semblance to a definite breeding season while the berry is being formed, and a maximum population by the time the coffee is ripe unless there have been inhibiting factors. If the bugs have been allowed to increase it is imperative to reduce their numbers before the crop is off the trees, to save the damage and disturbance to subsequent growth.

If large green berry food is available throughout the year on account of intermittent flowering, the *Antestia* may be able to maintain themselves in considerable numbers. Any cultural practice or environment which induces Arabian coffee to flower and fruit heavily in one season alone will reduce the severity of the pest. Robusta coffee is not attacked and is not affected by the bugs. In regions where bean rots occur, caused by *Nematospora coryli* or *N. gossypi*, infected *Antestia* can do far more damage to the crop. Such damage is relative to the number of *Antestia* present, and cases have been known where 97 per cent of the beans have been found rotted when the bugs have been numerous.[10]

The incidence of *Antestia* bugs is aided by the fact that they have been found to use several wild host plants of the *Rubiaceae* family. It is curious that robusta coffee is not favoured by them.

The maximum length of adult life of the bug is in the region of 30 weeks, and this added to the nymphal stages brings the total period during which a bug may do damage to about 9 months. The minimum period required for one generation, i.e., egg to egg, is 8 weeks, and a total of 460 eggs may be laid by one female during 23 weeks. The length of the life cycle and the rate of reproduction vary considerably according to temperature, and to the quantity and quality of the available food.[28]

At all times the bugs will move rapidly and hide among the foliage or berry clusters when approached. This, and the fact that the adults readily take to the wing, makes hand-picking difficult and entirely uneconomic. Even the use of smoke which causes them to run down to the basal portions of the tree at a time of the day when they are inactive, gives inadequate results and the cost is prohibitive. A far better method of control was that advocated in the middle nineteen-twenties by A. Ritchie in Tanganyika, i.e., Spray-baiting with poison. This, however, is only effective when done properly in dry weather. Spray-baiting should not be used in wet weather and it should not be intensive. All that is required is quick fine wafts of spray momentarily directed into each tree in turn, with a hand sprayer that can be turned on and off with a thumb switch. The aim is to have very fine globules of the spray mixture resting on the leaves and branches to which the *Antestia*, both young and old, are attracted to feed. The poison is such that if the spray mist is too coarse, and the globules too large, a severe scorching of the leaves results. Where the baiting is done carefully in hot dry weather, the bugs are either totally destroyed or reduced to negligible numbers. The formula of the spray-bait is as follows:

1½ oz. sodium arsenite and 4 lb. of crude or refined sugar in 4 gallons of water. This, when mixed, should be applied in a fine mist which must not produce visible wetting of the leaves. It should be directed upwards and into an open-pruned tree towards the main stem, and only a small volume of the spray suffices per tree—about 2 fl. oz. for the first application, and 1 fl. oz. for the second and third. Ritchie recommended a series of three baitings at

intervals of about ten days during dry weather, when little or no crop is found on the trees. The bait is less attractive to the bugs when green berry is on the branches.

Later, in the nineteen-thirties, Le Pelley advocated the control of *Antestia* in Kenya by means of pyrethrum, readily obtainable in the country. An extract was made by allowing kerosene of high flash-point to percolate slowly through good quality pyrethrum powder. A low-grade kerosene will cause serious scorching of the green parts of a tree. Concentrated pyrethrum extracts are now manufactured in East Africa and available locally.

Le Pelley advised[11] that each tree be covered in turn with a sheet of calico cloth. The required dose of the extract was given by means of an atomizing sprayer and the tree was kept covered for a few seconds. Considerable care and skill was required to avoid scorching the foliage, and the spray was not applied during rain, or wind, or when the trees were wet. It often happened that the spray was not strong enough and the bugs were merely stupefied and recovered after a few hours.

Most authorities in East Africa now advise routine testing to assess the numbers of *Antestia*, thus avoiding the use of control measures on areas of coffee that do not require treatment.[15]

The materials advised for testing are *double strength* extract of pyrethrum powder using kerosene of the grade used for lamps. Two pounds of fresh pyrethrum powder are soaked in one gallon of the oil for at least twenty-four hours and occasionally stirred. The extract is strained off before use.

Two men constitute a testing team and they carry with them three sets of calico sheets, each set comprising one top sheet 11 ft. × 11 ft. for single-stemmed coffee trees, or 15 ft. × 15 ft. for multiple-stemmed trees, and two bottom sheets each 8 ft. × 5 ft. in size. The men should also carry suitable containers to hold the bugs collected from individual trees.

It is recommended to test two trees per acre at random, i.e., to choose a tree by its number in a row before examining the actual bush. Two bottom sheets are placed on the ground, one on either side of a selected tree so that they overlap, and they should be well wrapped round the bole at the base. A top sheet is then thrown over the tree so that it hangs down evenly on all sides, after which the two workers thoroughly spray the leaves and branches, inserting the nozzles of their hand atomizers at different points and at all levels. Any bugs that drop on to the sheets are immediately collected lest they have dropped because of the disturbance and have not been affected by the spray.

The workers then proceed to two more selected trees in turn with their other sets of sheets, and after repeating their actions they return to the first tree. About fifteen to twenty minutes should have elapsed and a number of semi-paralysed insects may have fallen to the ground. The top sheet is then removed, the tree shaken, and the ground sheets removed after great care has been taken to collect any bugs which might lie hidden in the folds of the cloth. All sizes of bugs are placed in the container belonging to each tree, and the containers for each coffee block kept together and marked so that a count may be made at the end of the day's work.

It is a good plan to test shortly after a spray treatment, to discover the efiectiveness of the treatment and the spray used. Forty-eight hours should elapse before testing the effect of pyrethrum dust, but one week should pass before testing after the use of D.D.T.

Nowadays D.D.T. is used against *Antestia* at the Coffee Research Station on Kilimanjaro. It undoubtedly controls the bug, but the Kenya authorities are advisedly somewhat wary of its use, lest it should upset the balanced control of some other potential pests with resultant disaster. They say[7] that it should only be used where the *Antestia* population really justifies extreme measures. D.D.T. should never be used where mealy bug is a potential pest, and wherever possible when it is used, the various blocks of the plantation should be sprayed at different times to avoid killing the helpful parasites. Routine testing enables a planter to discover where a build-up is taking place, so that he need only treat those blocks of his coffee where the bug population is dangerous.

For many years now the Kenya Authorities have preferred to use pyrethrum powder alone for *Antestia* control, and would not dream of using anything else in areas where mealy bug has been troublesome.

Pyrethrum dusting has thus replaced the use of pyrethrum extracts except for test purposes. It is necessary to use finely-ground first-grade pyrethrum flowers for dusting. There is no residual effect, and while this is greatly to its advantage since the parasite population is not affected, it does permit the *Antestia* to build up quickly again from a severe reduction in numbers, particularly if the weather is hot.

Notley ('The Control of *Antestia* in Coffee'. *E. Afr. Agric. J.* XV: pp. 25–28, July 1949) discusses the three rival methods for the control of *Antestia*, i.e., arsenite baiting, pyrethrum dusting and D.D.T. spraying. The last method of control was developed by him in 1947. He gives some valuable figures for field tests carried out at Lyamungu, on Kilimanjaro, including costs and the population densities of the bug after the various treatments had been applied. He expresses the opinion that the continued use of D.D.T. has not resulted in outbreaks of other insect pests, but it should be remembered that the environmental conditions are different on Kilimanjaro. Moreover, the Kenya mealy bug is not present there and the biological complex is not perhaps so important at the present time.

Benzene hexachloride should not be used in present-day formulations because of the 'bricky' taint it gives to harvested coffee.

To sum up, the two least harmful and most helpful methods of *Antestia* control today are spray-baiting if done properly at the proper time, and dusting with pyrethrum powder. Both should be used in conjunction with routine testing with pyrethrum-extract spray. Notley[22] states that it does not appear that arsenite spray-baiting or pyrethrum dusting adversely affects the *Corioxenos* parasite population except indirectly by reducing the numbers of the *Antestia*.

Frappa[5] records serious damage on occasion by *Antestia clymeneis* Kirk., in Madagascar. He speaks of two forms of this species, i.e., var. *galtiei* and var. *flaviventris* and says that the var. *galtiei* prefers to attack coffee in the high plateau district.

COFFEE THRIPS

Diarthrothrips coffeae Will. and *Physothrips xanthoceros* Hood. The thrips which attack coffee in East Africa can suddenly build up to alarming proportions. They defoliate the coffee as though the leaves had been consumed by a fierce fire and so seriously weaken the trees that no crop can be gathered.

Many of the trees die, and at least two years' recovery is needed for those that survive.

Their presence is often associated with poor cultural-treatment, poor soil, unsuitable environment and lack of shade. They are always a potential menace where the rainfall is erratic, insufficient and when hot periods of droughty weather favour an outbreak. Cool and cloudy weather, sufficient rain, mulches and shade all go a long way to eliminate the fear of a Thrips attack.

Thrips are troublesome in Kenya and Tanganyika because much of the coffee is grown in regions where the rainfall is short and temperatures often too high. Indeed, it is becoming more and more apparent that temperature is the most important factor. If the temperature rises above a critical point a severe Thrips attack can be forecast with some degree of certainty, and for this reason both the Kenya and Tanganyika Authorities issue warnings of expected attacks to the planters.

Thrips are very agile and voracious feeders during their short lifetimes. For this reason the damage a few Thrips can do is out of all proportion to their size. They are tiny narrow-bodied insects about one-tenth of an inch in length, the adults having wings with a dense fringe of hairs. The early symptoms of an attack are greyish-green areas on the lower leaf surfaces speckled with brown spots of excreta. The upper surfaces exhibit a slightly yellowish appearance before the ultimate browning and shrivelling takes place. Later the whole of the foliage is shed and many of the trees die.

It often happens that certain portions of a plantation are always most subject to attack, so it is these that must be watched with a view to early and immediate action if a build-up of the pest begins. A few days of hot dry weather require the planter to be on the alert. Experience may teach him whether or not it is advisable to spray as a preventive measure at certain times of the year.

Various sprays are used against Thrips, and wherever they are, a thorough wetting of the foliage is generally advocated. One has a suspicion that the water used is almost as efficacious as the poison, for a heavy rainfall will usually put an end to an infestation. Mulching of the soil to preserve moisture and the resultant humidity will go a long way to lessen the severity of a Thrips attack. A still, hot atmosphere, dry leafage and exposure to the sun are conducive to the rapid multiplication of the pest.

The following mist spray formula is advised in Kenya: 40 gallons of water, 3 lb. fresh and finely-ground hydrated lime of high calcium oxide content, 8 oz. Paris green and 10 pints of molasses. A rough estimate of the quantities needed to keep in stock tc spray 100 acres are:

Lime 5 cwt.
Paris Green 1 cwt.
Molasses. 5 × 44 gallon drums.

These quantities are based on the maximum rate of application, i.e., 1 pint per tree.[16]

Metal drums for mixing may be used provided the spray is not mixed in combination with copper sprays. The water and lime may be mixed in advance, but the Paris green and molasses should be added just before the spraying is done. The Paris green should be made into a smooth paste before it is poured into the drum.

On no account should the mixture be allowed to stand for more than two or three hours before application, and it should be stirred as it is issued to the sprayers. A small dipper should be used to take out the liquid when the depth is only six inches in the drum. From then onwards stirring should cease and the last inch be discarded. These dregs must be washed out in a place safe from labourers and animals, and they should never be left in the drum when it is filled again with new spray mixture. The mixture should always be strained into the sprayer containers and the operatives be trained to agitate their containers while they work. The mixing centre should be sited in a shady place.

For spraying a large area in as short a time as possible, battery pressure sprayers are the best, and mention of these is made in the previous chapter.

The rate of application varies between ½ and 1 pint per tree, depending on its size. A correct mixture and a good quality lime will minimize the risk of leaf-scorch, but the method and rate of application are the best means of reducing this risk. *Unlike some of the other spray mixtures, a Paris green-lime-molasses mixture must be used as a fine mist which does not thoroughly wet the foliage.* More of the spray should be used under the leaves than above, and the spray nozzle held so that only a fine mist reaches the tree.

If a small portion of an estate is affected, spraying should first be directed at isolating this area and the sprayers should work into it from the circumference. Even so, if Thrips show any tendency to break out, the whole estate should be sprayed and the blocks least likely to be affected sprayed last of all. Repeated sprayings may be necessary, cycle after cycle, if the drought and the Thrips season is protracted. If a general attack takes place then the blocks that bear the heaviest crop should be the first treated and the remaining areas afterwards. Even if spraying is seriously delayed it is worth carrying out to aid the recovery of the trees.[16]

Kerosene emulsion, whale-oil soap, or resin wash sprays and proprietary sprays such as Derrisol, have been recommended for the control of Thrips. All these must be applied at high pressure in order to wet all parts of the plants. D.D.T. has been found most effective, but this should be used in emergency, and not as a general rule, because of its depressing effect on the parasites of other potential pests.

MEALY BUGS

Pseudococcus spp. The importance of mealy bug depends on the species, its position in the biological surroundings, the environment, and the cultural methods used. In certain parts of East Africa the various mealy bugs are more or less kept in check by biological means and it would be dangerous to take drastic action which might upset the balance. In Kenya, one species became a serious pest because it arrived, during the nineteen-twenties, without its parasites. It still is a serious pest when local outbreaks occur.

Mealy bugs and other Coccids always appear more prevalent when the cultural treatments are wrong, when coffee is weedy and neglected, when there is soil erosion, and lack of sufficient shade. Certain varieties of coffee appear more susceptible to attack than others, and the pests are often troublesome when the environmental conditions, especially in regard to temperatures and moisture, are not ideal for the species of coffee grown.

Hargreaves states[28] that records of *Pseudococcus citri* Risso on coffee

in Uganda date from 1914, and of *P. virgatus* (*Ferrisia virgata*) Ckll., from about 1916. There appears to have been some uncertainty regarding the identity of the forms of the former when they attacked the root and the shoot, since they have been named in succession *P. coffeae* Newst., *P. deceptor* Green, and *P. lilacinus* Ckll., the last name also having been given to the form found on the shoots of coffee. It is now known that *P. lilacinus* Ckll. is an oriental species, and the common coffee mealy bug of Kenya and Uganda has been named *P. kenyae* Le Pelley.

P. virgatus occurs on other plants in Uganda, such as cotton, and on some of the shade trees, e.g., *Leucaena glauca*, and *Gliricidia*, but it is said to be only a minor pest of coffee there. It is most troublesome on *Leucaena glauca* shade in Java and it spreads to the coffee from the shade trees.[1]

P. kenyae is generally distributed throughout the wetter areas of Uganda and in the adjacent Bukoba district of Tanganyika Territory. It has a number of host plants, some of which were listed by Kirkpatrick in the Kenya Bulletin No. 18. 1927, when it was known as *P. lilacinus*, and it is often abundantly present on *Gliricidia sepium*. It has also been seen on Mangoes, Avocadoes and the Roselle *Hibiscus*.

At least two species of ants are said to attend and protect the pest in Uganda, including *Pheidole punctulata* Mayr. which is so troublesome in Kenya. Indeed, when ants are seen climbing up the trunks of coffee trees, Coccids of some kind or another are to be suspected.

P. citri is found in most places in Uganda, where it occurs on *Cacao*, *Citrus*, cotton and turnips.[28] The root form, known as the 'coffee-root mealy bug', attacks both Arabian and robusta coffee. There are generally odd trees or small groups of trees infested, in which case the foliage turns yellow and the trees have a sickly appearance. The attack first occurs at the collar near ground level where ants remove the scaly outer bark and thus aid the mealy bugs to feed. The bugs are spread on to the main roots and smaller branch roots where they become inaccessible, and they are sometimes associated with a flexible rubber-like covering which is the mycelium of a fungus *Polyporus coffeae* under which the bug thrives. The infested trees may die, or live in a debilitated state for a long time, and the presence of the insect is often associated with a poor patch of soil or other influences contributing to a weakness of the trees.

Remarking on the incidence of mealy bug in the Bukoba district of Tanganyika Territory, Ritchie[25] agreed that the low incidence and lack of trouble in that region is probably in part due to the well-spread and sufficient rainfall, and to the gales which have the effect of cleaning down absolutely, or to a considerable degree, coffee infested by mealy bug. Especially is this so with smaller trees more recently established and the younger foliar colonies. He said that a gale in late June ruined his pot cultures of the bug.

He discovered *P. lilacinus*, now known as *P. kenyae* in the Bukoba coffee area, affecting the coffee to a minor degree, and he went on to mention that certain important biological factors were also at play. Neither did he consider the bug there to be an introduced pest, but one which had been present for a considerable number of years in an area as large as that concerned in Kenya.

Ritchie found a number of useful parasites which he described, among them *Anagyrus aurantifrous* Comp., which has been the controlling factor of *P. perniciosus*, Newst. and Willc., in the Arusha coffee area of the Northern Province. This is also an effective parasite of *P. citri* on citrus in South Africa.

Ritchie was well known to the author. A most conscientious and experienced entomologist, he relates during his discussion on mealy bugs several instances of a satisfactory control of ants by poison baiting. He quotes Kirkpatrick as saying 'were it not for this ant (*Pheidole punctulata*, Mayr.) it is scarcely too much to say that the mealy bug would no longer exist as a serious pest of coffee in Kenya.' Ritchie regretfully stated that poison baiting of this ant in Kenya had resulted in complete failure. He said there are ample beneficial insect forms in East Africa whose degree of efficiency is interfered with, and lowered or nullified by ant activity. 'The abolition of the ant nuisance by some inexpensive method is the end to be aimed at,' he continued, 'and it is clear that very much has yet to be studied and accomplished along this line.'

The common mealy bug, *P. kenyae*, became a dreaded and widespread pest on coffee plantations in Kenya in the nineteen-twenties, one that was only expensively and very inefficiently controlled by grease-banding every tree to prevent the ants caring for and protecting the pest from various predators and parasites. Neither did there appear to be parasites present at that time of the kind and quantity desirable. There was difficulty in preventing any of the thousands of coffee trees on a plantation from touching the ground at one point or another, thus permitting the ants access to the trees. The foliage of trees overlapped, and storms or the passage of labourers, or again the weight of cherry and prolongation of growth caused the tips of some branches to touch the ground. The grease-banding had to be done very carefully indeed on gnarled trunks to prevent the ants from passing underneath.

The introduction of parasites from Uganda in 1938, however, was followed by a period when almost complete control had been achieved. Although five parasites were liberated in quantity and can still be found, the successful biological control is attributed to one species namely *Anagyrus kivuensis* Comp.[17] To begin with, everything was in favour of the new parasite, because the forces which in time militate against such an introduction were not organized. A state of equilibrium gradually appeared to prevail, after which the newcomer had to exist as a member of a balanced biological complex, which is said to have been reached about 1943.

Although the parasite is still of great value, breakdowns in its power have been occurring both before and since 1943 in accordance with a fluctuation above or below a mean average control, depending on conditions of climate and environment. In general it is still highly successful, but under certain conditions the control may be upset.

It has been found, for instance, that the parasite itself can be attacked and severely depressed by a hyperparasite known as *Pachyneuron*. This form of failure is likely to occur when vigorous main-stem coffee-suckers become infested with mealy bug, or when Green Scale (*Coccus viridis*) occurs in quantity in the same area with the mealy bug. The same species of hyperparasite attacks the helpful parasites of both the mealy bug and the Green Scale. Biological control breaks down when the *Anagyrus kivuensis* is in turn attacked by the hyperparasite.

A more general and serious breakdown in control occurs during outstanding periods of drought which appear to depress seriously the activity of the parasite, though it ultimately regains control.

More frequent breakdowns of recent years have been associated with a change-over from single-stem to multiple-stem pruning, and they are con-

nected with a supply of succulent suckers on which the mealy bugs thrive. The reasons are not clearly understood, because, though the parasite does attack mealy bug developing on sucker growth, the hyperparasite appears to have the power to quickly suppress any increase in the primary parasite. A mealy-bug attack originating on sucker growth is thus able to develop rapidly, and if it is not checked in the early stages by direct means, the attack will develop on the rest of the tree. The attack may assume considerable proportions before the parasite is able to regain control, if it ever does so in the continued presence of young sucker growths and the disturbance these seem to cause.

In Kenya, nowadays, control of the common coffee mealy bug is left entirely to its parasite until a breakdown occurs. Meanwhile various practices are advised to guard against a breakdown.

Wherever Green Scale occurs, the authorities advise that it should be attacked at once with heroic treatments to eliminate the potential increase of the hyperparasite. Infested branches may be pruned away and burnt, and the infested trees sprayed with oil emulsion. Any isolated tree infested with Green Scale may be carefully grease-banded to isolate the Coccids from their protector ants. Among single-stemmed coffee trees there should be frequent de-suckering cycles to eliminate the aggravating material. Multiple-stemmed trees should be trained and pruned in succession so as not to produce a mass of sucker growth at one time. All surplus sucker growth should be eliminated from the beginning. Selected suckers should be spaced at a distance from the ground to give room for banding if this should be necessary.

When and if a breakdown occurs, badly infested suckers should be removed and burnt. At an early age and on regular monthly inspections, any infested sucker should be treated with methylated spirit. A small soft brush wetted with the spirit should be used and it is only necessary to touch the mealy bugs with the brush, though care must be taken to see that the job is done thoroughly. The methylated spirit treatment is feasible if it is begun early enough, for once the sucker growth has begun to mature the parasite can be relied upon to regain control.

Once an outbreak has occurred, measures must be taken to control the ants, and when a clean-up of mealy bugs has been brought about by the predator parasites, a weatherproof limewash should be rubbed into the bark of the tree at ground level and below the grease-bands which have been put in place.

The ants are prevented from mounting the trees by grease-banding provided a good type of grease can be obtained.

The use of D.D.T. in any mealy-bug area is not favoured by the Kenya Authorities on account of the risk to the controlling parasites. D.D.T. in itself is harmless to coffee. The Coffee Services advise that D.D.T. should be used only for banding purposes, i.e., applied to the lower trunks of the trees, and only in the form of an oil-in-water emulsion. It can be applied either with a mist sprayer, or by a soft paint brush, and the aim should be to treat a four-inch wide 'band'. None of the liquid must run down the trunk or soak into the ground. If more than one such treatment is given it is advisable to treat a different portion of the trunk the second time. D.D.T. emulsion should never be used on young trees, and when the trunks of the trees have been treated none of the branches must be allowed to touch the ground to form a bridge for the ants to climb into the trees.

At one time B.H.C. compounds were used, but even the small amounts required for banding the trunks of coffee trees were found to give a 'bricky' taint to the coffee bean.

A D.D.T. emulsion contains by weight 10 per cent of D.D.T.; 20 per cent solvent; 10 per cent paraffin, and 60 per cent water. It is conveniently made by mixing one 4-gallon tin of 'Grenade' Brand D.D.T. Concentrate with approximately 1 gallon of lamp-oil paraffin and 8 gallons of water. It is important to agitate the liquid frequently while it is being used.[17]

The weather-proof limewash is rubbed on below the banding after the mealy bug has been cleaned up, using a piece of old sacking. It kills the mealy bugs feeding among the bark scales by direct friction, and it fills up the bark crevices thus eliminating feeding places for new mealy bugs. About an inch of soil should be removed from the collar of the tree before the treatment is applied, and being readily visible, the limewash treatment facilitates inspection work.

The formula suggested for the weatherproof wash is as follows:

200 lb. lime.
14 lb. coarse salt.
1 gallon boiled linseed oil.

Cover the ingredients with water and stir. Add water to bring the mixture to a suitable consistency for application so that it is not too diluted and use at once. After the limewash has been applied, all new suckers must be treated with methylated spirit without delay if mealy bugs appear.

D.D.T. should never be used to control *Antestia* or Thrips in areas which have been, or are, affected with mealy bug. If D.D.T. must be used to control *Antestia* or Thrips in an emergency, then supplies of parasites should be obtained and liberated rather more than a month afterwards if such parasites are bred and obtainable locally.[18] If more than one odd coffee tree becomes infested with mealy bug, all the trees should be banded at once.

Mealy bugs of various kinds have been recorded as occurring sporadically wherever coffee is grown, but nowhere, does it seem, have they attacked coffee in such a widespread and serious manner as in Kenya. Should they ever do so, then the experience and manner of their control in Kenya should be carefully studied.

GREEN SCALE

Coccus viridis Green (=*Lecanium viride*). Almost invariably green scale will be found attacking single trees or groups of trees in association with a protective ant. If the trees are very badly infested a black mould fungus is often found growing profusely on the sticky exudations of honey-dew on the leaves, so that the trees look as though they had been showered with soot. The scales will attack young and old trees alike, generally in localities where the environmental conditions are not entirely suitable for coffee, or on poor patches of soil, sometimes on trees that have been badly planted and are in a weak state of health. Strong-growing and healthy trees generally resist an attack.

The green scale insect was responsible, along with the leaf-rust disease, for the ultimate abandonment of Arabian coffee growing in Ceylon, and both were indicative that the altitudes and localities, and perhaps the soil, chosen

for coffee in Ceylon were not suitable. Cultural neglect, and ignorance of how to combat the pest, would naturally lead to the infestation spreading throughout the estates.

In well-grown coffee, in a proper environment, green scale is only of incidental occurrence on older trees, though it may occur quite frequently on nursery stock and young trees. In appearance the scales are flat, oval and pale green in colour, clustered closely on the plant. They suck the sap from the green stems and leaves, impairing the growth of an infested tree. Natural parasites attack the scales, but these are prevented from exerting complete control by the protective ants. Hyperparasites also depress the parasites in accordance with varying and often temporary influences. Grease-banding to keep the ants at bay usually causes the disappearance of the scale.

During the grease-banding campaign against mealy bugs in Kenya, green scale almost ceased to exist, but now that a natural control has been supplied, outbreaks of green scale have reappeared with some frequency. It is always wise to take action against such a pest as soon as it is noticed and thus avoid offensive methods becoming necessarily defensive.

Control measures concern the pruning off and burning of as much infested growth as possible. A single badly infested tree might be entirely uprooted and burnt, though this should only be done after due consideration for it will leave a gap that cannot be filled in.

Repeated sprayings with paraffin emulsion should get rid of the pest. The emulsion should be made up as follows: Take 1 gallon of water and heat this almost to boiling-point. Then add ½ lb. of shredded yellow soap to the water, stirring until all the soap has been dissolved. Remove the pot from the fire and then add 2 gallons of high-grade paraffin, a little at a time, agitating the liquid vigorously with a pump, or by stirring with a stick. The success of the spray depends on the complete emulsifying of the paraffin in the soap solution at this time. The result should be a thick white cream which does not separate out into layers when standing.[19] This stock solution should be diluted with water when spraying is done.

Green scale must be thoroughly sprayed with a mixture made by taking 4 pints of the stock solution and mixing them with 4 gallons of water. The spray should be directed vigorously at the insects by holding the sprayer nozzle as close to them as possible. The spraying needs to be repeated every ten days until the pest is eliminated.

The pest is widespread and occurs in all countries of the world where coffee is grown to any extent. Though it is persistent and difficult to eradicate when once it has got a hold, it is seldom found on more than a group of trees here and there on any one plantation.

OTHER SCALE INSECTS

A visitor to an area such as the Bukoba District in Tanganyika Territory, where robusta and Arabian coffee grow side by side in an environment suited to the former species of coffee, would find a number of different scale insects living on the coffee. The area is one where nature is almost in balance, and the scales do little damage and are often hard to find in peasant plantings of healthy trees on fertile soil. It is only where the trees border on poorer patches of soil, or where they are neglected, sickly, and unshaded, that pests begin to appear in greater numbers.

There are several scale insects that attack coffee in different parts of the world. Like the green scale they sometimes appear among groups of trees, or break out for some special reason and assume the proportions of a dangerous pest. Unless this happens, it is wiser not to interfere with natural controls. The aim of this book is not to mention every insect that is found attacking coffee, but only those which become serious pests, and to indicate the most economic and modern means of controlling them. Most scale insects can be controlled by the methods outlined in the foregoing.

The star scale, *Asterolecanium coffeae*, is a case in point, for this can become a serious pest in East Africa. It attacks all the aerial parts of the tree, and if an attack is not controlled the tree may die. This scale may be widespread in a coffee area, and become troublesome on account of seasonal fluctuations. It may be controlled by the same measures advised for green scale. Thick encrustations of most scales appearing on the thicker stems can be treated by rubbing them with a piece of gunny sacking wetted with spray solution.

Again it must be emphasized that early action is imperative if trees are infested. It then often happens that only half a dozen trees need treatment. It is advisable that the treatment be thorough, even if this means that a man must work for an hour or two on one tree, and return to it in ten days' time. In such a manner can the beginning of an attack be overcome and a valuable tree saved. A planter owning thousands of trees is apt to be careless of their individual value. Nothing lowers the yields of an older plantation more than gaps which cannot be replanted.

STEM AND BRANCH BORERS OF VARIOUS SPECIES

To continue with this theme, perhaps none of the pests cause more gaps and are more dangerous to coffee trees than stem-borer beetles of various kinds. There are a great many such beetles which inhabit the wooded areas of various countries, using wild growths principally of the *Rubiaceae* family as their hosts, whence they are capable of invading coffee plantations in the neighbourhood. Some, like the white stem borers, have become dangerous coffee pests, and can be found in most places where coffee is grown.

Borers have been troublesome in Java. They invaded plantations in Nyasaland to such an extent that they are said to be partly responsible for the decline of the industry there, though they were a secondary cause. Of recent years the Government of Kenya has made it compulsory for planters to control the white stem borer at certain seasons of the year.[20] To give some idea of the possible extent of damage by the white stem borer (*Xylotrechus quadripes* Chev.) in India, the following counts were made in two localities during an experiment.[27]

Locality	*Particulars*
Chethalli ...	No. of trees = 1061 No. of damaged trees removed = 46 Percentage of infested trees = 4·34
Biccode ...	No. of trees = 1542 No. of damaged trees removed = 207 Percentage of infested trees = 13·42

In plantations of coffee that are not carefully watched, and especially in those where no action is taken to control borer pests, they can multiply to a prodigious degree and wreck the trees in course of time. In blocks of old trees, the yield of clean coffee can be reduced by more than half. Borers attack all species of coffee and can be very troublesome in robusta plantations. Their parasites exert a certain amount of control in favoured regions, and are assisted in their efforts when coffee is growing healthily.

Some of the worst of the borers, like some other insect pests, appear to prefer trees that are not in a vigorous state of health, i.e., those that are grown on poor eroded soils or in environments that are not ideal for coffee. This may have something to do with temperatures, with the moisture or sap content of the wood, or because the parasites are also depressed in environments unsuited to coffee on account of erratic rainfall or some other cause.

The larvae of the insects do the most damage, and according to the species, they attack and tunnel into the tips of young growths or the harder wood of the branches, and into the bark or the wood of the main trunks. Several larvae may operate in one trunk, and so extensive may their tunnellings be that the trunks break and the trees fall over, or the trees are so weakened that they die.

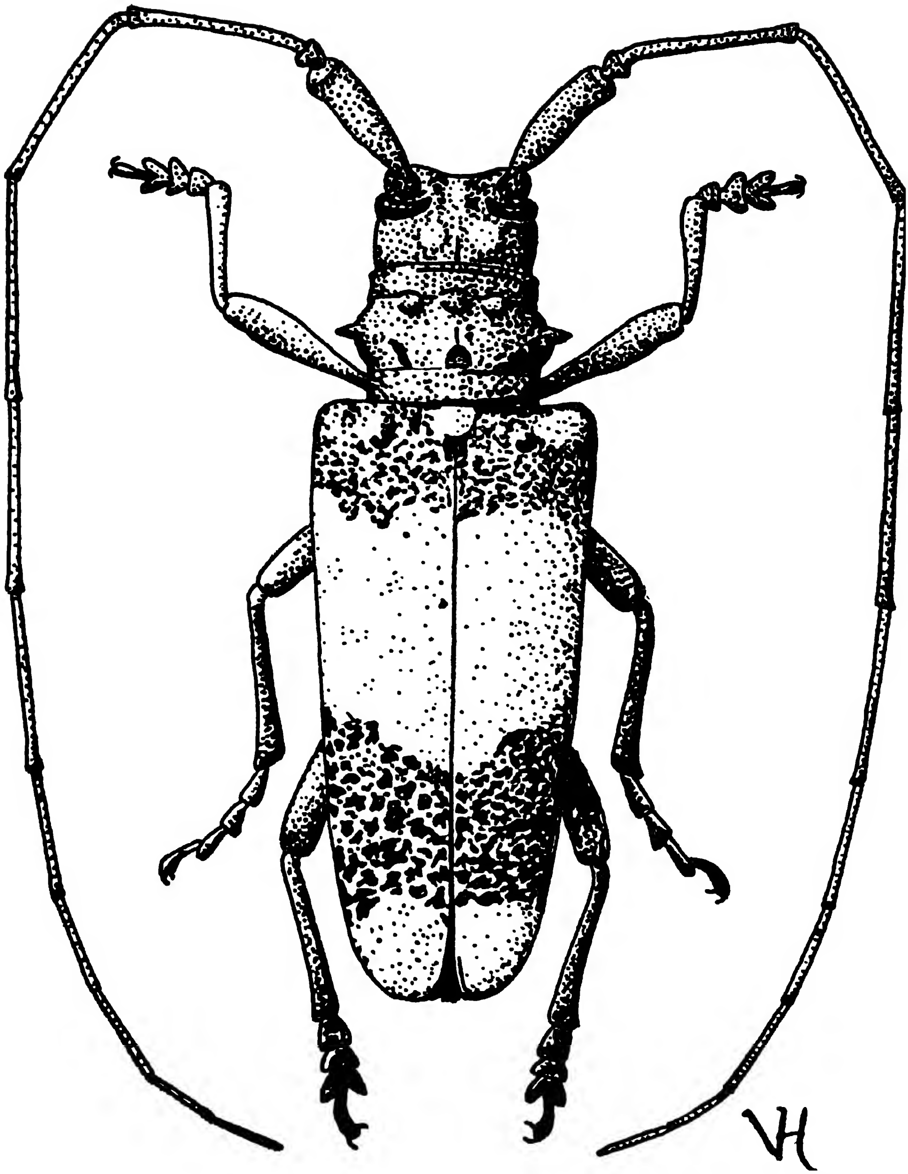
The White Stem borer, *Xylotrechus quadripes* Chev. has been, and still is, one of the most important pests attacking coffee in India.[13] In Kenya and East Africa, in general, the White borer, *Anthores leuconotus* Pasc.,[3] is the most serious borer beetle pest. Both occur in many coffee-producing countries. (*See* Fig. 32.)

The adult white borer is a large elongated beetle, dirty white in colour, with blotchy markings of dark brown. The female is slightly larger, approximately 30 mm. long, with shorter antennae than the male, though the antennae of both curve backwards and in the male are about twice as long as its body. They may be found in all African territories where coffee is grown at altitudes up to 5,300 feet. An account of this beetle is given at length as an example of the kind of damage these stem borers do, and to give guidance regarding the best methods of control.

Vigorous trees are seldom attacked, and those in poor health which show marked debility are generally chosen by the beetles.[9] Borers are, therefore, more troublesome at the lower altitudes in Africa.

The eggs are laid under the bark of the thicker main stems, and the incubation period is twenty days to thirty days. The dirty white grubs have powerful mandibles for boring into the wood, and at first they tunnel under the bark, excreting small particles which look like sawdust. As the larvae grow larger, frass-like strands of woody material are ejected out of the borings. In about thirty days, minute particles of wood may be seen protruding from the incisions in the bark through which the eggs were laid; at this stage the larvae have progressed about one inch from where they hatched. During the bark-boring stage and during the next two and a half months, the larvae may average a distance of a quarter of an inch per day and they descend spirally towards the roots of the tree.

When the larvae gain strength they begin to bore into a soft spot in the wood, and the entry usually takes place under a primary root where it joins the main stem. Ordinarily the larvae are then three and four months old, and for almost two years from this time they tunnel steadily upwards in the wood of the tree. When they enter the wood the larvae are about one inch long, but



By courtesy of Mr. W. Victor Harris

FIG. 32.—White borer of coffee, *Anthores leuconotus*. Length of body, 28 mm.

by the time they are ready to pupate they may be three inches long and half an inch in diameter. They are then creamy in colour and distinctly segmented.

As they proceed upwards, the larvae tunnel outwards at various intervals to the bark, on which they feed, and the chambers in which they pupate are made so that only a thin covering of wood remains for the adult insects to pierce before they gain the bark and the outer air. The frass is always coarser when the larvae are about to pupate.

The pupal period is between thirty-eight and forty-two days[3] and this stage in their lives is passed just before the rains are about to begin. Two or three weeks elapse before the beetle, after emergence, attempts to liberate itself, and this is effected by biting out a circular hole about 10 mm. in diameter. The emergence occurs about a week after the first heavy fall of rain.

White borer beetles are inactive on dull days, and their food consists of the bark of coffee branches, the young shoots, and the skin of green berries, though this damage is never severe.

The larvae are particularly vulnerable when they are boring in the bark. At this stage the bark should be rubbed vigorously with any coarse material so that the outer bark is removed and the larvae passages revealed. By following these, the larvae may be found and destroyed. It is best to carry out this work about three to four months after the eggs have been laid, since the larvae will then be big enough to locate. Most of the eggs are laid on the trunk near ground level so it is only necessary to examine the base of the tree at this time. The time is gauged from shortly after the adults emerge during the rains, because they begin to breed at once.

The older method of destroying the larger larvae in their tunnellings was by the use of a hooked piece of wire. The soil was removed about nine inches deep immediately at the base of the tree to uncover the forks where the lateral roots branch. Within a few days the larvae exhibit their presence by the frass which they extrude. Patience is needed and several visits per tree before control is effectively gained, after which the holes are filled in so that egg-laying cannot take place below ground level.

Nowadays instead of using a hooked wire, the larvae are fumigated in their tunnels with a mixture of one part of ethylene dichloride (75 per cent)/carbon tetrachloride (25 per cent) and one part aviation spirit introduced on a piece of cotton wool to the open end of the tunnel, the entrance hole subsequently plugged with wet earth.[20] Hand collection of the adult beetles is considered of great value and large numbers may be caught by children if cash incentives are given, with prizes, perhaps, at the end of the season to the children who catch the greater numbers.

A new formula using D.D.T. or B.H.C. mixed with resin, applied to the bark of the tree, is promising to be successful. It is persistent because the insecticide slowly crystallizes on the surface of the resin.

Some of the stem-boring beetles such as the Black Stem Borers of Uganda, *Apate indistincta* Murr., and *A. monacha* Fab., occur sporadically without causing extensive damage in East Africa.[28] They usually bore clean-cut circular tunnels obliquely upwards in the main stem, their presence obvious by the frass produced. The beetles are usually attracted to single trees or groups of trees, and several beetles may be found in one coffee stem though not in surrounding trees. They do not appear to breed in the coffee, and apparently emanate from dead wild growths in the country. Control may be

effected by spearing the beetles with wire, by fumigation and by hand-collecting the adults.

Apate monacha Fab. is very prevalent on the West Coast of Africa, especially in Togoland, French Guinea and the Ivory Coast. It is said to be partially controlled during the wet season on the Ivory Coast by a fungus which attacks the larvae.

By courtesy of Mr. W. Victor Harris

FIG. 33.
The Black Coffee Borer, *Apate monacha*.
Natural length, 16 mm.

The flute-holing yellow-headed stem-borer *Dirphya* (*Nitocris*) *princeps* Jord. is somewhat more dangerous, especially in regard to Arabian coffee trained to the multiple-stem method.

The larvae of these beetles bore into the soft tissues along the centre of a branch and then continue to tunnel through the wood of the main stem towards the base, even beyond and into the tap roots of young trees. The eggs are laid under a flap of green bark near the tips of the branches, and the larvae bore into the soft pith towards the tip of the shoot before turning round and boring into the older wood.

At intervals along the branch and stem the larvae make circular holes increasing in diameter from a pin-point to two millimetres, always in a straight line, through which they gain air and extrude the frass. These holes aid in the detection of the pest. The adult beetle emerges from the stem through a circular hole about seven millimetres in diameter. The adults are active and

feed on the thick veins of the leaves; they strongly resemble a hornet when in flight. *Dirphya usambica* Kbe. is another species which causes trouble in East Africa.

There are several parasites which help to control these borers. Direct control entails pruning away branches beyond the tunnellings of the borers before they reach the main stem, and burning the prunings. Fumigation may also be used against any larvae present in the main stem.

The Stem-borer *Bixadus sierricola* White, can also be troublesome in plantations of coffee near wooded land, and there is evidence that shade encourages this pest.[28] As many as 50 per cent of the trees of an estate may be attacked, and the larvae do serious damage to the trees by tunnelling in the bark, thus ring-barking the stems and causing the death of parts above. The larvae ultimately bore horizontally into the wood and then turn upwards for a distance of several feet before they pupate. The adults eventually emerge through a hole nine millimetres in diameter.

Hargreaves[28] advises the use of *p*-dichlorbenzene and says that a few crystals pushed into the bore-hole, subsequently sealed with stiff clay, will kill the larva in its tunnel. The bark of trees in regions where the beetle is a potential menace should be rubbed clean of lichens and scaly bark so that an attack may be detected by regular inspections. Portions of the trees that have been killed should be cut off at sufficient length without delay and any larvae destroyed. Species of *Bixadus* are particularly troublesome on the French Ivory Coast, West Africa. *Bixadus sierricola* White has done great damage in peasant plantings in French Togoland. Until recent years the methods of cultivating coffee there were most primitive. Trees were planted far too closely in unsuitable locations, where neither the soil nor the environment was good. Often the soil was light and shallow, overlying hard pan, so that the trees grew spindly and weak, ragged and defoliated, many of them in a half-dying condition. This state of affairs permitted the *Bixadus* to prosper, and as a result of their attack it has been necessary to choose better sites and improve the cultivation of peasant-grown coffee in recent years.

Species of twig borers of the *Xyleborus* genus are common in many parts of the world. *X. coffeae* Worth. is prevalent in Mauritius and Madagascar, *X. compactus* Eichh. in Sierra Leone, *X. morigerus* Bldf. and *X. morstatti* Hag. in the East Indies, and *X. discolor* Bldf. in Indo-China. These can be very troublesome and they are responsible for considerable loss of crop, so it is important to discover their presence immediately and take action before they get out of hand.

Pruning away and burning infested branches is about the only cure. In Madagascar the adult beetles are said to be attracted to light, so it may be possible to collect them in this manner soon after they emerge at night during the breeding season. It is suggested that hurricane lanterns may be placed on half-bricks in the middle of large white enamel hand-basins containing water, and that these might be placed at regular intervals in a plantation. The practice might be tried for most adult borer beetles.

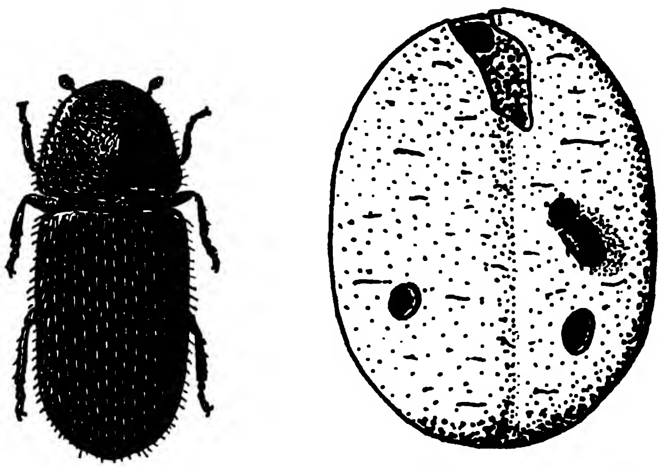
The control of all stem and branch-boring insects depends firstly on close and continued observation of the trees, and is the reason why, elsewhere in this book, the advice is given to train all headmen of labour gangs to keep their eyes open, and to report and mark the incidence of any pest or disease in its initial stages.

BERRY AND BEAN BORERS

There are several berry pests of little importance to the coffee industry, but one, at least, which is of great importance.

This is a species of *Stephanoderes*, to wit *S. hampei* Ferr. It is indigenous in Uganda and N.W. Tanganyika,[25] and it is this species which is referred to as the coffee bean borer.

The beetle is capable of causing serious damage to crops when infestations are intense. Several authorities state that the pest is usually more troublesome in dense shade. Others say that robusta coffee is preferred. Some estates of Arabian coffee, however, were badly infested in Uganda in 1914–16 when they were not shaded at all, albeit the trees had been badly planted and severely weakened by weed growth. The weeds had often grown so high that



By courtesy of Mr. W. Victor Harris

FIG. 34.—The Bean-borer Beetle, Stephanoderes.
Left—Adult beetle greatly enlarged. Natural length 1·5 mm.
Right—Coffee bean showing damage and one beetle.

much of the crop in the previous year could not be gathered and was lost on the ground, doubtless forming breeding material for the insects. When the plantations were properly cared for in later years, the incidence of bean-borer in the Arabian coffee was insignificant.

Hargreaves[28] considers that a low altitude is a predisposing factor, since the pest is never serious at high altitudes in East Africa or Java. They are said to be most destructive in Brazil in low, warm and humid valleys where the insect has become a scourge in widespread areas planted with Arabian coffee.[25] It has been prevalent in Java for many years and has invaded several other countries.

Heavy shade and close planting appear to favour the insect, possibly because of a moisture complex, since there would be too great a competition for the moisture in the soil. Wider spacing and the reduction of shade has immediately reduced an infestation. Dense shade may possibly reduce the population of the controlling parasites.

Damage to the crop is caused primarily by the adults which bore into the seeds where they breed. The larvae continue burrowing, so that one or both

seeds become valueless, or the beans are partially tunnelled and become defective. Rots and discoloration occur while the defective beans are being fermented and dried, so that the expense of sorting before sale is greatly increased and the quality is lowered. Hargreaves has recorded the life history and biology of the insects in Uganda.[28] He states that the beetles show a marked preference for the older berries in which the beans consist of compact tissue, since they cannot breed in the moist tissues of younger beans. There is thus a moisture content in relation to infestation.

It has been found, for instance, that the beetles cannot survive for longer than five days in cured coffee with a moisture content of 13·5 per cent or less in the case of Arabian coffee, and 12·5 per cent or less in robusta coffee. A moisture content of about 20 per cent is essential for breeding, and these findings are important when cured coffee, which might be infested, has to be transported through country where the beetles are not present.

Natural controls hold the pest within bounds for long periods in countries such as Uganda and N.W. Tanganyika, where they are assisted by the correct environment and by proper methods of cultivation. Elsewhere, as in Brazil and Java, attempts have been made to introduce and liberate useful parasites. The management of shade, adequate spacing and mulching the coffee rows all help to reduce, or to avoid infestation, just as sanitation, such as clean picking, the avoidance of fallen cherry and the overlapping of seasons by growing more than one kind of coffee together, will help to prevent the pest breeding continuously throughout the year, and from one year to another. It would not be wise to attempt to arrange for the staggering of harvesting if the bean-borer beetle was a scourge in an area.

Direct control measures by spraying have been tried and found uneconomic or useless, and even sanitary measures such as stripping small crops, or collecting fallen berries from the ground are not always wise. Useful parasites may be eliminated as well. Hargreaves says that when *Prorops* parasites are present and well-distributed, dried over-ripe berries on the tree or on the ground are largely beneficial, whereas if the parasite is absent they would merely provide breeding material for the pest.

Since no other measures can generally be advised, it is necessary to consider any new and serious outbreak on the spot and to call upon the local advisory authorities for help.

LEAF MINERS

Leucoptera coffeella Guer., *L. caffeina* Washbourne, syn. *L. daricella* Meyr. These pests can do severe damage by defoliation, and they are listed among the major pests because they may become widespread, although they are largely kept in check by useful parasites. A great deal of work on them has been done by Notley and Kirkpatrick in Tanganyika.[22 23] The moth larvae tunnel in the tissues of the leaves, of course, just as leaf miners do in those of other crops, thereby destroying the leaves and interfering with the proper nutrition of the coffee trees. In extreme cases trees may be killed, in severe cases they are weakened so that loss of crop and die-back occurs, but at other times they may be a nuisance because they interfere with the perfect health of the tree and result in a slight loss of crop.

Although both species of *Leucoptera* are found intermingled, they may be separate since the *L. coffeella* appears to be more prevalent on unshaded

coffee while the *L. caffeina* is generally found in densely-shaded coffee. *L. coffeella* Guer. has the power to become an important pest in Brazil. A serious outbreak occurred in the years 1860–62, and another outbreak took place in the São Paulo region in 1944. Coffee in Brazil is usually unshaded.

The incidence and increase of both is controlled by parasites, if they are in sufficient numbers. The position is complicated by hyperparasites for if they are influenced or aided to increase, then the parasites are reduced. The swing of the seasons, the intensity of light and shade, dry weather and moist days, all appear to affect the breeding rates of the pests, and the incidence of the parasites and their hyperparasites. Much has yet to be learned regarding the reasons why the pests may gradually assume a greater dominance and appear in the nature of an outbreak. They are seasonally more significant than at other times, and since the larvae are buried in the leaf tissues there is little one can do against them that would outweigh the risk of upsetting the natural controls by eliminating the parasite complex.

To avoid a serious outbreak, the best means is to help the parasites to exist in abundance. Coffee should be shaded where the *Leucoptera coffeella* is likely to be prevalent, but the shade must be regulated and never allowed to become dense for fear that *L. caffeina* should succeed. Beyond this the coffee must be kept in the best of health by proper spacing and mulching. Leaf miner pests elsewhere in the world may offer similar complexities, and if attacks are severe it would be better to seek advice of the local pest control authorities.

Minor Insect Pests

The author apologizes for the bias given to East African affairs in this chapter, and also for not mentioning many a pest which has been listed by other writers as occurring on coffee in African or other countries. The literature is too voluminous, determinations are not always accurate, and many of the pests have little economic importance. Even when they have, a reference to a similar pest mentioned within this chapter should indicate the best methods of control. An attempt has been made to quote examples of the different classes of pests, the kind of damage they are capable of doing, and how such damage may best be avoided. It would take a whole book to contain all the information that exists in the world on coffee pests alone.

A reader must be astonished by the array of pests already recorded, and anyone intending to plant coffee might well feel it wise to try something else. He will read that any one of these pests may so damage his coffee as to rob him of a high percentage of his yields. Let him remember, however, that despite these pests, stout-hearted and hard-working planters have managed to make coffee growing a profitable venture.

Only one warning is necessary. Pests can be overcome with first-class cultivation, by watchfulness, and by immediate action. The expense of pest and disease control must be estimated for. When the price of coffee is moderate to high, such expenses can be borne even by marginal estates in environments not entirely suited to coffee. It is when prices drop severely that finances become strained. Economies in cultivation are then practised with an immediate effect on the pest incidence. Economy in pest control may make matters worse, until the planter finds his El Dorado a myth.

LEAF- AND SHOOT-EATING CATERPILLARS

There are many kinds of caterpillar which have been known to become, or which might become, a potential pest of coffee. The first generation may hatch out from eggs laid among the leafage, and the larvae are at first quite small. It is essential to destroy that first generation to avoid the adults breeding and egg-laying over a widespread area of a plantation. At first it is usual to find a caterpillar infestation affecting just a small portion of an estate, perhaps part of a block of coffee near a boundary and adjacent to wild herbaceous growth. Only a few trees may be affected, in which case careful hand-picking will clean up the trouble.

Some caterpillars are very sensitive to smoke and when they get a whiff of it they drop immediately to the ground. The author has cleared an acre of caterpillar-infested coffee by using smoke torches, first spreading sheets below the coffee from which the larvae were collected.

Sometimes caterpillars appear regularly every year. If they appear suddenly and are widespread, it is possible that the first generation has been missed. If the time when they may be expected is known, then spraying can be done as a preventive measure. A lead-arsenate suspension, using 3 lb. of powder in 100 gallons of water, will remain on the foliage for several months if the weather is moderately dry. If an infestation has begun, spraying should be done at once while the insects are quite small.

There are caterpillars that tend to spread among the branches, others that show tendencies to migrate, and still others known as bunch caterpillars which bunch together among the young green leaves at the ends of each twig. Species of the *Metadrepana* genus have done serious damage in East Africa when they have been unchecked, as also has the coffee hawk moth, *Cephonodes hylas* L.

There are leaf-roller caterpillars, leaf-skeletonizers, and leaf-tiers, some of which appear to luxuriate in dense shade. They do not generally appear widespread or become serious pests. Except for occasional outbreaks, many of the caterpillars are controlled by natural parasites. Care must be taken to distinguish between leaf-rolling caused by caterpillars and leaf-curling caused by a thrips.

LEAF-CURLING THRIPS

Hoplandrothrips marshalli Karny. This thrips occurs in Uganda on coffee, but has never been a serious pest. The insects cause the leaf margins to curl upwards in a fairly tight roll. They feed on the leaf surfaces within the roll, the outside of which is usually rugose. When fully-grown, the thrips vacate the curled leaves and their abode is then often occupied by spiders.

The adult thrips is black with pale brown antennae, and about 2 mm. long. The young thrips is a pale yellowish-brown. It usually attacks odd leaves in shaded coffee but sometimes a tree will have many curled leaves.[28]

CUTWORMS

Euxoa spp. These are caterpillars which move sluggishly and sleep curled up beneath the soil surface during the day. They are brownish, greenish or greyish in colour, and bloated in shape, and they emerge at night to feed upon

young tender growths and shoots near ground level. They can do considerable damage to young coffee and kill young plants that have recently been planted out, by cutting off the stem at ground level.

Cutworms live on the vegetation which normally covers the ground, and when the ground is cleaned of weed growth in preparation for planting coffee, the larvae are robbed of their food and hungrily turn to the young coffee plants as soon as they are planted out. If the soil is mulched, the cover protects them from their enemies, and the moisture enhances their chances of living, hence cutworms are often more damaging in young mulched coffee.

Control is usually effected by ploughing in a cover crop or a weed growth several months before the young coffee is planted out. Squares of tin may be rolled to form a protective collar round the young plants and these should be pushed into the soil for about half an inch.

CAPSID BUGS

Lygus sp., *Helopeltis* sp., *Lycidocoris* sp. Some of these plant bugs are noted for their attack on the flower buds and young leaves. Individually they are not widely known as serious coffee pests, though they are potentially serious and can do severe damage in any locality of any coffee country. Many have alternative hosts among forest growths, and parasites which keep their numbers within bounds. For some reason the natural controls may break down and the pest increase in numbers. A rapid build-up is assisted in those regions where either Arabian or robusta coffee develops a succession of flowerings in place of one distinctive seasonal flush.

These bugs cause the abortion of the flower buds and hence a severe loss of crop wherever they occur. The Kenya Authorities say that they require control when they exceed an average of four bugs per tree.[15] Control concerns spraying and routine testing as advised for the *Antestia* bug. In emergency a D.D.T. spray might be advisable, though this should be avoided because of the effect it might have on the parasites of other potential insect pests.

THE LACE WING COFFEE BUG

Habrochila placida Horv. This insect has occurred of recent years on *Cacao* in the Congo Belge and on coffee in East Africa. It is generally a minor pest but it has been responsible for almost the complete defoliation of coffee over small areas. In 1951 severe damage was caused on two plantations in Kenya, and these were the only ones in the region where D.D.T. spraying had been carried out previously against another pest. The entomologist reported that there was a strong indication that the outbreaks had been caused by the effect of this insecticide on the natural enemies of the Lace Wing Bug. It is considered that the predator *Stethoconus* sp. is capable normally of exerting a strong control on this pest.[28 20]

The general symptoms are said to be strongly reminiscent of thrips attack. After an intense infestation the yellowing leaves become brown, then wither and are shed. The predator insects are very similar in size and colouring to the bug, but their rapid movement and extreme readiness for flight when disturbed serves to distinguish the predators from the pest.[28] Pyrethrum dusting has been suggested against the active stages of the bug but it will not kill the eggs. Nicotine sulphate and soap mixtures have not proved very useful, and

both dusting and spraying should be attempted only when the predators are absent or scarce, and when the bug infestation is high.

APHIDES

Aphides, often termed 'blight', may be found on the young leaves. They are generally seasonal and of minor significance. Spraying with a nicotine-soap solution is, perhaps, the safest and best means of overcoming them.

BERRY-BORING INSECTS

Berry-boring caterpillars, for instance the *Deudorix lorisona* Hew., will attack clusters of green berries and eat out each berry in turn, but the pest has generally been of minor importance. Beetles which bore into dried unpicked coffee fruits, such as the *Sophronica centralis* Aur., may do damage when dried cherry is stored for some while; otherwise it is a minor pest. The larvae of fruit flies of which there are several species in East Africa will also invade ripening cherries, but they feed only on the mucilaginous pulp and merely tend to dry out the cherry a little, and cause some trouble in pulping, so that it would not be economic to take action against them. According to Ritchie[25] there are several parasites which attack them.

SYSTEMIC POISONS

There are new and powerful systemic poisons marketed which may be incorporated in the soil or sprayed on leafage. These are absorbed into the tissues of plants. Those added to the soil are taken up by the roots and render the whole sap of the plant poisonous to sucking insects. They are not dangerous to the parasites and control only the pests themselves. However, their disadvantages outweigh their advantages in the hands of unskilled workers. Their use must be timed so that the product, in this case the cured bean, is not rendered poisonous to consumers. There are usually too many risks to operators and to consumers alike for the authorities in tropical countries to permit or advise their use.

SPRAYING MATERIALS AND EQUIPMENT

Spraying, dusting and other pest-control equipment should be maintained in sufficient quantity and in good order. Sprayers, containers, tubing and spray nozzles should be thoroughly cleansed before being returned to store. Chemicals and substances required should be stocked in adequate quantities, stored in a cool dry store, properly labelled, and kept under lock and key. It is wise to keep a book of recipes handy, in which all the formulae and methods of mixing are clearly written down, listing the pests against which they are of use.

In addition to this, it is advised that a careful record should be kept of every pest outbreak, with as many entries as possible concerning the weather and other influences. Such a record may give valuable information as to when and where a pest may be likely to recur, and of the methods found most efficacious in dealing with them in the past.

OTHER PESTS

EELWORMS. NEMATODES. VARIOUS SPECIES

Eelworms are very troublesome in some countries. In Java and the Dutch East Indies as a whole, eelworms were so bad in some regions that they became one of the reasons for trials with budded and grafted material. Some forms of Liberian or excelsa coffees (their determinations were doubtful) had been found to be immune, or almost immune to attack, and hence it was desired to graft the more valuable species of coffee on rootstocks which were immune. Immunity is sometimes varietal within a species, and this is a matter that requires more research by responsible authorities.

The presence of eelworms usually denotes that the area planted with coffee has been used in the past for other crops. They are seldom found in so-called virgin soil that has borne wild vegetation for many years. Eelworms often appear cosmopolitan in their choice of hosts and the same species may be found attacking tea and coffee. Hainsworth[6] says about eelworms and tea: 'When selecting the nursery site a piece of jungle-covered soil should be chosen. Virgin forest or thatch land is most suitable, but if it is necessary to use old land then at least ten years during which it has lain fallow and become covered with jungle, should have elapsed between tea plantings.'

Eelworms will attack nursery plants and the younger stock when planted in the field. The plants grow sickly and stunted; their leaves turn yellowish and may fall off. The roots are gnarled and swollen and may have a watery appearance, quite different from that of normal roots, and the microscopical worms may sometimes be seen with the naked eye.

There is not much that can be done when a patch of soil is infested with eelworms. It would be better to plant it with grass and use the grass for mulching. To avoid eelworms, a nursery should not be sited on old land that has been cultivated, and one should be wary about planting up land with coffee that has been cultivated before. If eelworms are discovered on a patch of soil, care should be taken that they are not spread to clean land by anything which will carry soil, such as tools and boots which have not been thoroughly cleaned.

Soil fumigants and rotations may be used to lower the percentage of eelworms in the soil for annual crops, but these methods do not apply to a permanent crop such as coffee.

RED SPIDER

Red spiders are not insects, so they are included here. The author has seen a shaded coffee plantation in southern Tanganyika coloured throughout a vivid pink by countless hordes of red spiders. The state of the coffee trees can be imagined.

The root causes were obviously soil and climate. The soil was of a fine sandy texture, almost a volcanic ash, infested throughout with nut-grass, indicating waterlogging during the wet season. The rainfall records exhibited an uneven spread with long periods of dry weather, an environment which in all respects was totally unsuited to coffee. To control red spider, even to try to grow coffee in such a situation, was entirely uneconomic.

Red spider is never likely to be serious in an environment suited to coffee,

though it may occur in droughty weather on marginal estates. Control might be effected by using a Derris spray, provided the outbreak was recognized in time. The spiders look like little red specks and they are usually found on the underside of the leaves. As they are very active, one or two spiders on a leaf can do considerable damage, and the effect they have on a plantation can be likened to a bad attack of thrips.

If proprietary brands of pest control materials are used, reference to the United Kingdom Ministry of Agriculture and Fisheries approved lists of Crop Protection Products should be made. A list would be sent to anyone who asked for it and the list is renewed and brought up to date every year. The products are classified and the names of the makers with whom one may correspond are given. It will be seen in the 1954 list that there are eighteen Derris sprays of various kinds. The makers should be given full information if their advice is asked.

NOXIOUS WEEDS

Except for certain animals peculiar to a country, there are no other classified pests which may be dangerous except noxious weeds.

Noxious weeds are those with creeping underground stems, species of grass akin to couch grass, and the deeper-growing spear grass, nut-grasses of the sedge family, and other weeds with creeping stems peculiar to certain countries. None of these must be allowed to infest the soil, and all must be entirely eliminated before the coffee is planted. Ordinary agricultural methods of ploughing and raking will not do, for every piece of root must be dug out to avoid trouble when the permanent orchard is established.

Mulching will do much to prevent such noxious weeds getting a hold while the coffee and shade trees are young, provided a watch is kept for the tiny beginnings of a patch which can be dug out immediately, without expense or trouble. Later, as the trees grow older and begin to touch, and the shade grows overhead, the danger of an infestation of noxious weeds will have largely passed. Then, only the boundaries of an estate need be watched to avoid encroachment from outside.

Chapter XV

COFFEE PRODUCTION IN AFRICA

ABYSSINIA

ACCORDING to Pierre G. Sylvain, coffee specialist of the Food and Agriculture Organization, who has been studying the wild coffees of Abyssinia on the spot, and who has kindly communicated with the author, there are a number of forms of *Coffea arabica* L. growing wild in the country. He states he has seen more than ten and suggests that there may be others. The form he has most commonly observed in the forests is similar in many respects to var. *bourbon*, but it often presents flowers with persistent calyces rather more developed than in the other varieties, with the exception of the mutant known as cv. 'goiaba'. He presumes that this is a primitive character which has disappeared in other forms throughout the years.

The forests in which coffee is found growing are generally between 6° and 9° latitude north, and 34° and 38° longitude East, in the province of Kaffa-Gimma, Ilu-Babor, Wollega, Gamu-Gofa and Balle (Harargi). Most of the forests are found at altitudes between 4,920 and 6,132 feet, which he states corresponds to temperatures averaging about 68° F., with little variation between the seasons but considerable variation in the diurnal temperatures. The rainfall is relatively well distributed with a yearly average between sixty and seventy-eight inches and no more than three to four months consecutively with less than two inches.

Dr. Sylvain has also presented the author with advance notes of a report entitled *Yemen and its Relation to World Coffee Problems*, written by himself for F.A.O., and dated 24th August 1954. In it are interesting facts which, despite the fact that the Yemen is in south-western Arabia, are included in this chapter.

ABYSSINIAN COFFEE IN YEMEN

Following the recent survey carried out in the Yemen coffee-producing regions, it is very doubtful whether Yemen is the native home of coffee. Despite the fact that no worthwhile meteorological data are available in Yemen, it is known that the rainfall is nowhere well distributed enough or plentiful enough to provide the ecological conditions necessary for an 'Arabian' coffee and forest community. In addition, the soil types are not of the right kind.

Nowadays, most of the coffee cultivated as a commercial crop in Yemen is irrigated to ensure a yield. Even if the climate was considerably wetter in remote years long before the thirteenth or fourteenth centuries, the species could hardly have survived the lack of rain since then, without being taken into cultivation.

As Sylvain states, wild or pseudo-wild coffee in Ethiopia is always found under forest cover. On the other hand, nobody has reported the existence of forests in Yemen, where the common trees are *Tamarix* spp., *Zyziphus spina-cristi*, *Acacia* spp. and other xerophytic trees not usually associated with

coffee. *Cordia* sp., are seldom seen beyond the irrigated areas. There do not appear to be as many forms of Arabian coffee in Yemen as in Ethiopia, and none of the primitive types with persistent calyces, such as are common in the latter country.

Most of the coffee forms seen in Yemen were bronze-tipped; one form was similar to the Harrar coffee of Ethiopia, and another similar to the type species *Coffea arabica* var. *arabica* L. In several plantings green-tipped forms were found mixed with the bronze-tipped, the colour of the young leaf flushes being the only difference. In the district of Wadi Rema, many of the trees are green-tipped, and in appearance resemble *Coffea arabica* var. *bourbon* Choussy. All these forms were found to be long-seeded, but beans from Bazey which were seen in Hodeida were rounded, like the seeds of the 'Cioiccie' form of Ethiopia.

The temperate climate of the coffee-growing areas of Yemen may account for an absence of serious diseases. It appears that the cultivation is very primitive. The seeds are apparently sown at stake with several seeds to one hole, thus a multiple tree growth is produced at each spacing as is still practised in Brazil.

Yemen coffee used to be exported through the port of Mocha. It is said that the plantations on the southern slopes of the Yemen mountains are nearly 10,000 ft. above sea level,[9] and that the best coffee comes from the district of San'a, at 7,000 ft. in the Jebel Harraz area, though the altitude figures may be somewhat exaggerated. Up to the Turkish period and during World War I, Mocha was a flourishing sea port and a centre of the entire trade, but the wells dried up and most of the inhabitants had to leave. Coffee nowadays is exported largely from Hodeida.

Possibly on account of varying altitudes and treatments, the coffee comes forward for export all the year round though there is a peak in summer. The beans are often packed in straw baskets or bales, and brought on camel back to the port, those from Jebel Bora and the Jebel Rema being considered inferior.[9]

The coffee business at Hodeida is said to be chiefly in the hands of Greek merchants, and there are two big firms, one the house of Livierato which has been in existence since the opening of the Suez Canal. There is a sorting business at Hodeida and several depots on the African coast and in Ethiopia. Head offices are in Aden. After being sifted, cleaned, and sorted, the coffee is exported in bags of 160 lb. each, mostly for export to America, while the remainder goes to France, Egypt and Italy.[9]

COFFEE PRODUCTION IN ETHIOPIA

In recent years, news of high prices for coffee has naturally filtered through to the coffee regions of Ethiopia. Coffee has, therefore, been taken into cultivation on a small but enlarged scale, though in a somewhat primitive manner by the natives. The product finds a market through itinerant buyers, and much of it crosses the Straits of Bab el Mandeb to Aden where it becomes involved in the sorting, mixing and bulking in the coffee merchant's storehouses. Aden is a sort of clearing house for coffees from Yemen and Ethiopia, and for the poorer qualities of coffee in 'buni' cherry from East Africa The altitudes at which the coffees are grown, and the dryness of the Arabian air, doubtless co-operate in enhancing the liquoring qualities of 'Mocha' coffee.

Nyasaland

HISTORY

The 'Nyasa' coffee was introduced into Nyasaland in 1878[1] by Scottish missionaries, and the planting material was obtained from the Blue Mountain region of Jamaica.[11] By 1891, there was a flourishing industry in the Mlanje district. The industry reached its peak in 1900 when 17,000 acres were cultivated by Europeans established throughout Ncheu, Blantyre, Zomba, Mlanje and Cholo districts.

CAUSE OF DECLINE IN PRODUCTION

It must be remembered that knowledge of the methods of cultivating coffee at this time had been gained by experience in the West Indies, India and Ceylon. Planters still had much to learn regarding the choice of climatic conditions and soils, the dangers of erosion, and the proper spacing, pruning, and methods of pest and disease control. Looking back over those years it is surprising how little was known.

The climate and soils of the coffee regions in Nyasaland left much to be desired, and they were such as to lure planters on with hopes of success. It is well known now that long dry periods, a shortage of evenly distributed rainfall, and warm temperatures have a good initial effect on Arabian coffee. Growth is fast, flowering profuse, but this is followed by bumper crops which create exhaustion. In other words the trees over-bear their strength and degenerate afterwards in health and stamina.

Mistakes in the choice of environment and in cultivation were largely responsible for the later decline in production, and for all the ills which affected the coffee plantations, because as soon as there were large areas of trees in poor health, pests began to take their toll and yields began to fall. With falling yields it was soon found that, just as in Ceylon, tea was a better paying proposition.

On account of erosion and lack of cultural knowledge the soil was quickly impoverished.[10] Root diseases became prevalent, as also did the white stem borer beetle; thus gaps were caused by the death of trees which, assisted by over-bearing and the resulting periods of recuperation, caused yields per acre to fall to disastrous levels. The environmental conditions were marginal,[1] and without modern methods of amelioration, the outlook was hopeless from the start. Whereas the peak production was 2,000,000 lb. in one year, production fell until exports were nil. The following table shows the production and exports during comparatively recent years. (*See* Table).

Coffee had been held up by lack of shipping during 1941 and this accounts for the increase in exports during 1942. Doubtless the difficulties encountered during the war contributed to the reduction in acreage from 1939 onwards.

Coffee in Uganda

THE BEGINNING OF THE PLANTATION INDUSTRY

Because Sir Harry Johnston, who was the Special Commissioner in Uganda in 1899, favoured the development of plantations under European

Year	*Acreage*	*Yield in lb.*	*Exports in lb.*
1938	421	48,160	28,179
1939	365	26,656	11,552
1940	200	14,224	4,441
1941	59	6,608	10
1942	48	6,160	10,049
1943	37	6,160	—
1944	27	4,150	—
1945	25	1,462	—

management, grants of freehold land were made at a ridiculously cheap rate between the years 1900 and 1916. Experimental plantings of coffee had promised exceptional returns, and a number of early pioneers were persuaded to begin planting. Businessmen in the country were also convinced that coffee had a bright future, and they invested in numerous estates with the idea of encouraging British capital to join with them in creating an industry. They had every reason to believe that the proposition was sound, and they found no difficulty in raising capital for the financing of several syndicates. In these the local men kept a share, and they acted as local managing agents, export and import agents and general advisers. Unfortunately no one in Uganda in those early days had much knowledge of how coffee should be treated, and they had to learn as they went along. The roving managers who were employed were seldom qualified in either horticulture or agriculture, and these formed the acquaintances and colleagues of the author who, at the age of twenty, was dispatched to Uganda in early 1914 to manage a 500-acre estate.

The fact that the author found the plantation he was to manage bearing its first good crop, is an illustration of the primitive conditions that then existed. The coffee was red-ripe on 500 acres of young trees, yet the weeds were shoulder-high throughout. Only one hand pulper had been provided, with about two dozen drying trays, and these were entirely inadequate to deal with the crop. One Hamali hand-drawn cart was considered sufficient for transport, and the labour supply was about a quarter of the full requirement.

It took three years to get that plantation in ship-shape order, and meanwhile the coffee bushes suffered from neglect during the years when they should have been bearing excellent crops. There was insufficient drying space for the parchment coffee as it was taken from the boxes, which served in lieu of concrete fermenting tanks, so the parchment coffee had to be heaped up too thickly on the drying trays, and it then had to be stored half-dry in cribs and store-sheds until the peak period of harvesting had passed. Of course it heated, lost colour, and acquired a musty odour, and since many of the plantations were labouring under the same difficulties, Uganda Arabian coffee started with a bad name on the London market.

In 1917 the author was given two other plantations to manage at a distance of fifty miles. These were 600 acres apiece, and made the area for a young man to manage, without assistance, a total of 1,700 acres. These other plantations had been under the control of native headmen who could barely

read or write, and planting was in progress on the day of first inspection. The young trees were being planted with a chopping hoe, in holes no bigger than a child's pail, and it was in this manner and under such supervision that many of the early estates were planted.

The plantations were mostly situated east and west of Kampala within ten to fifteen miles of the lake shore, though there were a few to the north-west in the direction of Hoima, and others further west at Toro.

In the region of Buganda near the lake, the country is composed of a number of flat-topped hills with rolling country in between, and valleys filled for the most part with swamp and papyrus sudd. Bordering the swamps are patches of jungle forest, and above these on the lower slopes of the hills, the land, where it is not occupied by the people, is covered with elephant grass, *Pennisetum purpureum* Schum., growing on a fertile well-drained lateritic soil. The upper slopes of the hills are thinly covered with soil and shorter grasses, while the tops are characterized by outcrops of ironstone. It was on the sloping sides of these hills that much of the Arabian coffee was planted, with no safeguards to prevent erosion. Roadways were cheerfully taken up and down the slopes with drainage from branch roads emptying into the ditches cut beside them. By 1918 sheet erosion had taken much of the soil from the higher slopes and gully erosion had become serious.

All sorts of misguided ideas were put into practice to stop the erosion; hedges, weed windrows, silt pits of many shapes and sizes were all provided at great expense and proved to be of no real value. Clean weeding was stopped during the wet seasons and mulching with grass was begun, but some of the slopes were too steep for any efficient means to be attempted on land that was closely planted with fully-grown trees.

Throughout the period 1910 to 1920, plantation owners were of two minds. They did not know whether the estates were to be planted permanently with coffee, or whether rubber would be the ultimate crop. The Hevea rubber was interplanted at a 24 ft. spacing among Arabian coffee planted 8 ft. by 6 ft. apart, and it grew so fast that the coffee was soon overshaded by trees which could not be lopped to reduce the shade. Even then, no one would sacrifice the coffee, and the bushes were so densely overshaded that the crops they bore were hardly worth picking.

By 1920, the bottom had dropped out of the rubber market, and exchange rates were against the country. It was costing more than 1s. 6d. per lb. to produce rubber which often sold at less than 7d. per lb. By this time the coffee had been ruined by the shade, and much of it was being cut out.

But before this, from 1916 onwards, *Antestia* sucking bugs had made their appearance in such fantastic numbers that most of the coffee berries dropped when they were about half size. If no fruit was available the bugs punctured the young growths and caused a prolific growth, having a 'witches' broom' appearance. None of the modern insecticides were available in those days, so planters struggled to collect the eggs and the adult insects or relied on an increase of the natural parasites, which did, in fact, bring the pest under control for short periods.

Throughout the chief coffee-growing area the climatic conditions were not ideal for the Arabian species, since the temperatures were too high and the rainfall inadequate. The shortage of rain and the high temperatures could, however, have been ameliorated by the use of proper shade and mulching, and now that powerful means are available to fight *Antestia* bugs, the author

wishes he could try growing Arabian coffee again in those very areas of Uganda where it is now considered to be unsuited. The amenities of the country for the production of Arabian coffee have been blamed unjustly, because the methods of treatment were responsible for 90 per cent of the failure to make of it a thriving industry.

In 1914, as if there were not enough troubles besetting the poor planter, the first world war began. Many a settler left his plantation in the hands of native headmen and volunteered for service. One, at least, stumped his coffee, covered the ground with a thick mulch of elephant grass, and left it to the care of the Almighty. From then onwards, many abandoned coffee planting, and those that remain today are wiser men, numbering about fifty.

EARLY PEASANT PLANTING

In the early days the natives had also been given Arabian coffee seed, and had been permitted to grow patches of coffee. These could be seen in all stages of neglect as the years sped by; they were often weedy, unpruned, and grand breeding places for all the pests and diseases known or unknown to coffee. Except in certain favourable localities which have since been developed, one might truthfully say that the African people gave up growing Arabian coffee in Buganda Province long before the Europeans decided to abandon planting, or to grub their Arabian trees and plant robusta instead.

The following table is from Dr. Tothill's book[27] and summarizes the waxing and waning of Arabian coffee planted by Europeans in Uganda. To illustrate the importance of the change-over from Arabian to robusta coffee, and without including figures of native plantings, the European acreage devoted to robusta coffee totalled 6,946 acres by 1934.[13] Tea was also planted on some of the acreage formerly under Arabian coffee.

ACREAGES OF NON-NATIVE ARABIAN COFFEE IN UGANDA

District	*1910*	*1915*	*1920*	*1925*	*1930*	*1935*
Mengo	407	8,462	7,793	5,638	3,269	2,208
Entebbe ...	—	1,177	2,819	1,495	567	42
Masaka ...	—	1,279	945	1,372	903	412
Mubendi ...	—	754	3,536	1,951	1,450	117
Busoga	—	1,630	1,305	1,727	635	211
Toro	—	582	1,607	2,063	4,583	2,461
Bunyoro ...	—	502	2,778	3,158	2,042	680
West Nile ..	—	—	—	—	—	155
Totals ...	407	14,386	20,783	17,404	13,449	6,286

CLIMATIC INCONSISTENCIES

It has been stated in two books[13, 27] that the rainfall in Uganda is too evenly spread to allow the successful cultivation of Arabian coffee. The author does not agree; in fact he feels confident that the fault lies chiefly in the high maxi-

mum temperatures, and secondly in the insufficiency of the rainfall; faults which might be ameliorated by regulated shade and constant mulching.

Good rain showers are necessary to promote blossoming, and no horticulturist could believe that rain would damage the coffee when the flowers were spiking, a term used for the elongated buds before they open. Even when the flowers open, the manner in which the rain falls in Uganda should not hurt them, because the showers are usually followed by a long burst of hot sunshine. It must be remembered that coffee is self-fertile, and that most of the fruit is set by its own pollen. Furthermore, Indian research has shown that, as would be expected, good rains are required to set and swell the fruit, and they should never be harmful on a well-drained soil. The author believes that a well-spread rainfall of eighty inches or more is required for Arabian coffee. The drier months should be after harvest, when the growths that have taken place during the wet season need ripening and hardening for the following year. Even then, good showers are required to sustain the trees while they are recuperating after bearing a crop.

THE ORIGIN OF THE ARABIAN SEED

Arabian seed was introduced into Uganda by the government, and also by the Catholic missions, but it is not known which was the first seed to arrive. That which the government imported in 1900 came from Nyasaland, and became known as the 'Nyasa' strain, and this appears to have originated from the West Indies.[27] It was, in fact, the *Coffea arabica* var. *arabica*, known in Brazil as var. *typica*, and it proved in Uganda very susceptible to *Hemileia* leaf spot, and to pests in general. Since it became commonly used on most of the plantations, this may have contributed to the failure of Arabian coffee in Uganda. Had 'Kent's' coffee been planted, then the tale might have been a different one.

The Nyasaland seed was sown at Entebbe in 1901, and the resulting plants gave such excellent promise that a distribution of seed and seedlings was begun in 1903. By 1904 several hundredweights of seed had been distributed in the country. A small quantity of the variety 'Maragogipe' was also imported in 1901, and seeds from the Blue Mountain region of Jamaica and from Guatemala were sown in 1903.

Meanwhile in 1900 a Fr. Moullec returned to Uganda from leave. Travelling by an old caravan route, he brought seed from the Morogoro mission station which was situated in what was then known as German East Africa. This proved to be *Coffea arabica* var. *bourbon*, and only two plants were raised from the seeds which were planted at Nandere near Bombo. This Bourbon coffee had been taken from the island of Réunion to Morogoro, and thus it was derived from the original importation of seed from Arabia.

Seeds from the two plants successfully established at Nandere were later distributed to a number of the Catholic mission stations in Uganda and Kenya, but when the mission at Kisubi near Entebbe planted this kind of coffee extensively in 1906, a large quantity of seed was also obtained from the Catholic mission at Nairobi.

THE POOR COLOUR OF UGANDA ARABIAN COFFEE BEAN

For some reason, possibly connected with the warm and humid climate,

the colour of the cured Arabian coffee beans was generally poor in Uganda, despite later efforts to treat and dry the coffee quickly and efficiently. Most estates used wire trays on which the parchment coffee was dried in the sun, but some installed power machinery and mechanical drying. Almost all the coffee was produced and exported as parchment coffee until curing works were established in the country. From then onwards much of the coffee was hulled to save freight, and this was important when exports were restricted on account of the shortage of shipping during the first world war.

THE USE OF BETTER TREATMENTS DURING LATER YEARS

Despite the initial errors of the early days, which took irksome years to put right, considerable progress had been made in cultural methods by 1920, especially in connexion with the younger plantings. Planters exchanged views at well-attended planters' meetings, and were greatly assisted by advice given by Officers of the Department of Agriculture. Much greater care was exercised in the raising of seedlings and in the planting of them in the field. A distinct preference was shown for eight- to nine-months-old plants, rather than the cut-back stumps so fashionable at that time in Kenya, and these were usually planted in holes never less than 1 ft. wide by 1 ft. 6 in. deep.

The young trees were all grown on the single-stem method without capping, and stopped at about five feet high. Spacing was increased from 8 ft. × 6 ft. to 8 ft. × 8 ft., and planters who relinquished the idea of interplanting rubber trees began to plant shade trees instead, chiefly *Albizia falcata* (moluccana) and *A. chinensis* (stipulata). In 1931 a Mr. C. H. Lankester was employed by the Department of Agriculture, and following his experience of coffee planting in Costa Rica, he advised the multiple-stem pruning of coffee in place of the single-stem. In spite of all these efforts, the cultivation of Arabian coffee declined in favour of robusta coffee which did not suffer to the same extent from *Antestia* attack, and was more suited to the climate. The slumps which occurred in the early nineteen-twenties and again in the nineteen-thirties hastened the need to find a crop which would not require so much trouble and expense.

Today, therefore, there is only a small production of Arabian coffee. One or two planters in favoured localities at Toro to the west still grow small acreages; some of the Africans of Buganda still have bushes growing here and there among their robusta coffee, and a co-operative African venture exists on the slopes of Mount Elgon to the east.

CHANGE-OVER TO ROBUSTA COFFEE

Although the European plantations existed at altitudes of between 3,800 and 5,500 feet, it must be remembered that the equator passes within a short distance of Entebbe. Moreover, there is the proximity of the lake with the moist and warm winds passing over it from the south-east. The climate is thus more suitable for robusta coffee than Arabian, and it was known that robusta coffee was indigenous in some of the Uganda forests.

Trials were carried out with various species of coffee at the Government Plantations, Kampala, in 1915–16, when a Mr. T. D. Maitland interested himself in making selections from some of the 'robusta' strains, mainly gathered from the indigenous *Coffea canephora,* though parcels of robusta seed were also imported from Java. As a result of these trials, selections were

found which were considered to be superior, including a Toro selection from which the well-known No. 9 strain was derived. As the coffee samples from these received favourable reports in England, a distribution of robusta seed to both Europeans and natives was soon begun. The Africans began to take a serious interest in robusta coffee planting for profit in 1922, and the following figures are given of native plantings.[26]

	Total acreage under coffee	Acreage under robusta coffee
1914	14,753 ...	367
1930	18,594 ...	1,024
1934	13,391 ...	6,946

Early use of robusta coffee for chewing

It was easy to interest the Africans in planting robusta coffee because of their long association with this species, which grows wild in their country, and which had long been used for chewing and ceremonial purposes. In the northern and western forests of Uganda, wild robusta coffee is often abundant, and is then dominant in the small-tree layer of the forest.[27] Thomas states that mature specimens are tree-like, usually fifteen to twenty-five feet tall, and often having trunks up to eight inches in diameter.

To avoid journeying to the forest to obtain their coffee beans, natives of the Province of Buganda began to plant coffee among their banana plantations. At first large cuttings about three feet long and one inch thick were taken from old forest trees, and these were bent in the form of wide inverted U's, with both ends forced into the ground to form arches. Ultimately they rooted at both ends, and grew into bushes, and it was not until comparatively recent times that seedlings were preferred for planting.

The following shows how easily the older wood of coffee will root: the author stumped back old Arabian coffee trees in Uganda, cut off the laterals, sharpened the tips of the coffee trunks and used them upside down as stakes for fencing. More than 50 per cent sprouted the reverse way, when the old stems rooted at their tips.

A most important centre of early robusta cultivation was on the Sese Islands, where planting material was introduced from the Kasai forest on the mainland, and the product was later traded back to Buganda for chewing purposes. As Thomas says,[27] it is not surprising that in the early reports on Uganda, coffee is mentioned as a potentially important export crop. At the beginning of the twentieth century, the export of native coffee, mainly from the Sese Islands, developed rapidly, and in 1902 the value of the robusta coffee exported was £892.[27]

The beginning of the robusta industry

Not much attention was devoted to the development of a robusta coffee industry until the year 1918, when Maitland's selections had proved so promising. In 1923 it was decided to begin a large-scale distribution of robusta seedlings to Africans of the Mengo, Entebbe and Masaka Districts, and also to those in Bunyoro and Bwamba. A number of nurseries were laid down from which many thousands of seedlings were ultimately distributed free of charge to the African people. At the same time instruction was given in how to space and cultivate the species.

The policy of encouraging the planting by Africans of robusta coffee has been continued to the present day, with an eye directed to the growing of sufficient food at the same time. The coffee industry fits very well into the economy of the country, since the cotton crop flourishes best in the drier regions where coffee will not prosper.

The 'No. 9 Selection' of robusta which at first was distributed widespread in the native areas, was later superseded by the *nganda* variety which does not grow so tall. In fact, as will be seen in the chapter on pruning, it soon grows into a dome-shaped bush and it did not call for much intelligence in the task of training the tree, or in the subsequent pruning operations. Today, the *nganda* variety is still preferred for African planting, and the government has persisted, and has been largely successful, in trying to control the kind of coffee planted by the natives.

Meanwhile the European planters turned to robusta strains which had been imported from Java by the Mabira Forest Co. in 1911; these were mostly of the upright type of growth. They also planted the No. 9 selection which has a large fruit and a bolder-sized bean. They planted their robusta ten feet apart and trained it to the multiple-stem system. Whereas several have planted trees to give overhead shade—and the Agricultural Department is in favour of a light overhead shade of the right kind—all are convinced of the advantage of mulching with banana trash or elephant grass, a practice which is now widespread and has been fully discussed in the chapter on maintenance.

A. J. Thomas[27] gives the following estimated figures to show the increasing importance of robusta planting before the second world war.

ROBUSTA COFFEE

	Acres	
	1925	*1935*
African	338	17,100
European and Asian	946	5,975

H. B. Thomas and Robert Scott[26] give their estimated figures for 1934 including Arabian coffee as:

Year 1934	*Acres*	
	Arabian	*Robusta*
African	11,371	19,278
European and Asian	6,445	6,946

The Uganda Department of Agriculture gives the acreages of robusta coffee in 1947, some thirteen years later, as:

Year 1947	*Acres*
	Robusta coffee
African	146,993
European and Asian	17,591*

*Includes a small quantity of Arabian coffee.

A speech by His Excellency the Governor of Uganda in 1953 mentioned that the robusta crop for the season beginning 1st November 1953 was expected to be 30,000 tons. He said that the export value of coffee during the 1952–53 season, including 3,400 tons of Arabian coffee, was approximately £10½ million. In all the coffee-growing areas new plantings were made on a considerable scale during 1953, both by African peasant farmers and by the estates, and high prices stimulated interest in the improvement of established coffee and the rehabilitation of abandoned plots.

Preparation of robusta coffee

Plantation robusta is prepared by the wet method, because the fruit is picked and pulped when ripe and afterwards fermented, dried and hulled. Either disc or cylinder pulpers are used, and though robusta coffee fruit does not contain as much mucilage as Arabian coffee, yet it can be pulped satisfactorily, provided it is picked at the proper stage of ripeness, and ample water is used during the pulping process. It is fermented in bulk in tanks of various designs for about sixteen hours, then washed and drained on wire trays. Afterwards it is sun-dried on trays or on concrete barbecues, with arrangements made to prevent it being wetted by showers of rain. Rotary dryers are used on some estates during peak periods of harvest. Sun-drying takes from eight to ten days in good weather.

The Africans pick their robusta fruit when ripe and place the berries in the sun to dry, usually on cane stagings on which matting has been spread. The dry cherry is known locally as 'kiboko', and it is either sold as such, or it is pounded in large wooden mortars with pole-like pestles to remove the husk, and the coffee is then marketed as clean bean. Nowadays most of it is hulled from the dried cherry.

HYGROSCOPIC PROPERTIES OF COFFEE BEANS AND DRIED CHERRY

Experiments in Kampala demonstrated considerable hygroscopy in coffee.[27] Drying is not continuous, it seems, for some of the moisture eliminated during the day is reabsorbed each night, and even in storage there is diurnal fluctuation in the moisture content of dry coffee. The average amount of moisture in both Arabian and robusta coffee beans is about 11·3 per cent of the total weight, no matter how they have been treated during the preparation processes. The hygroscopic properties of the pericarp of dried cherry are more marked, and the fluctuation in moisture content much greater. The average moisture content of dried robusta pericarps is about 13 per cent, and of Arabian coffee 16·5 per cent, so it is essential that buni (Kiboko) coffee should be kept in a dry store, especially when the humidity of the outside air is high.

CONTROL AND MARKETING

In the nineteen-tens and nineteen-twenties Arabian coffee was shipped to London in parchment, where it was cured and sold in Mincing Lane under the estate marks. It was understood that the parchment covering protected the coffee from taints and that the polish was dulled during the time cured bean was shipped to London. The London tasters often complained of grassy or musty flavours, and this is not surprising because of the inadequate

arrangements for drying coffee on the estates, and the use of swamp water for washing. As a young man, the author remembers listening to an elderly and respected member of a well-known firm of London brokers, who listed the causes of defects in coffee from Africa. Among these was a curious disease which, he stated, caused a shoulder of many of the cured beans to shrink inwards. It would have been ill-advised to have told him that the beans had been nipped by a maladjusted coffee pulper.

African-grown Arabian and robusta coffee found its way to merchants in Kampala, and often left the country in an unsatisfactory condition. It was chiefly for this reason that a Coffee Grading Ordinance was enacted in 1930, though it was not enforced until 1932.[26] Before this a Coffee Board had been established in 1928 to advise on matters affecting the Uganda industry.

The new legislature demanded that all native-grown hulled coffee for export should pass through licensed curing works and obtain an export certificate from a certified grader. Rigorous standards of quality for both Arabian and robusta coffee were established, and there were eight licensed curing works by 1934. The African robusta coffee is bought by licensed buyers at scattered centres, who resell it at the curing works where it is hulled if necessary and graded for export. The coffee was exported under 'F.A.Q.' (fair average quality), 'U.G.' (under grade), and 'triage', the buying season starting in October and ending in February. New rules introduced in 1955 made five numbered grades 5, 10, 15, 25 and 50, indicating the number of defective beans, and grade 15 roughly corresponds with the former F.A.Q. For Arabian coffee the new grades are 5, 15, and 30. Triage and hand-pickings are sold separately and it is presumed that grading in the Bukoba district of Tanganyika will follow this procedure.

Under the Coffee Grading (Amendment) Ordinance of 1932, estate coffee exported under the estate-owner's private marks, was exempted from all the provisions of the principal Ordinance, since it was obviously in the interests of each estate to maintain the quality at the highest level.[27] The plantation 'washed' robusta coffee commands a premium over the African cherry-dried hulled coffee.

Soon after World War II began, shipping became difficult, London markets were closed, and marketing through normal commercial channels became impossible. Shipments were allocated in accordance with the decisions of the London Food Council. In 1947 the Ministry of Food entered into a five-year contract to buy a proportion of the Uganda crop. Their first contracts with East Africa contained a clause prohibiting the Ministry from re-exporting coffee, and after the contracts had been negotiated, world prices rose to a considerable extent. A delegation which visited the United Kingdom early in 1950 arranged a revision of these contracts, by which the prices paid for purchases from the 1949–50 crops were approximately doubled, and those for the remaining two years of the original contracts were to be determined in accordance with world prices between the new 1949–50 rates and new floor prices. The clause preventing the re-export of coffee was deleted and the Ministry was thenceforward permitted to resell its contractual purchases in hard-currency countries.

The proportion of the East African crops, including Uganda coffee, not covered by these contracts, was sold by auction in Nairobi or Mombasa, a method of disposal and sale which had started before the war.

A marked change in the method of sale of East African coffee has, therefore,

taken place during recent years, hastened by the difficulties experienced during the war. With the introduction of bulk buying in the United Kingdom it became essential to establish marketing organizations in the separate countries, and co-operative selling agencies and marketing boards were brought into being.

In regard to the local marketing of Uganda robusta coffee and, in fact, the Tanganyika Bukoba robusta as well, it became the practice to label the native-produced robusta coffee as 'hard' coffee, which is, of course, untrue. Departmental reports have also on occasion referred to this coffee as hard, and as London merchants have pointed out, this is a disservice to the producers and to our own economy. East African robusta coffee is a mild coffee and by no means hard, and the governments concerned should vigorously suppress the use of this term. It was mistakenly applied to the coffee because it was prepared by the dry process, and because the price in New York for Rio 7 provides a guide to the world value of robusta coffee.

In spite of the recent reopening of the London coffee auction markets, the central marketing agencies have come to stay, and a great improvement of African-grown coffee is expected on account of the introduction of centralized mechanical processing in both Uganda and Tanganyika Territory. In terms of the Uganda Coffee Industry Ordinance of 1953, the Government invited applications from African interests for permission to erect six new coffee-curing works, and the preferred siting of these new curing works was in the vicinity of the following places: *Mengo District*, Mityana, Bombo, Nakifuma, Mpigi; *Masaka District*, Masaka and Kalisizo. Successful applicants were required to erect curing works equipped with the machinery necessary to produce the best grades of coffee of not less than 1,000 tons of clean coffee per annum. With substantial sums accrued from the export levy on coffee and ample land suitable for extended cultivation, there is nothing to hinder a still greater production in Uganda, other than a world reduction in price.

In the year ended on the 31st August 1952, 32,305 tons of Uganda Native coffee were marketed from the 1951–52 crop, when about 80 per cent was of the robusta F.A.Q. grade, which sold at prices ranging from £350 to £370 per ton.[3] The figures for previous seasons were as follows:

	1948/49	*1949/50*	*1950/51*
Tons	22,938	23,185	30,931
Price range per ton ...	£130–£250	£170–£330	£280–£350

Note.—Non-native production averages about 4,000 tons per annum.

The object of the 1953 Ordinance was to improve the primary marketing facilities for the African producers, to provide for the participation of Africans in the processing of coffee, and to set up a Coffee Industry Board which will be responsible for the general organization of the industry. An export tax is to be levied on all coffee exported from Uganda to replace that which had formerly been levied on native exports alone.

BUGISHU ARABIAN COFFEE

An account of coffee cultivation in Uganda cannot ignore the progress of the African Arabian coffee production among the Bugishu people on a belt of

land extending for about thirty-five miles along the southern and western slopes of Mount Elgon. This belt varies in width up to a maximum of ten miles, at an altitude of from 4,200 ft. to 7,500 ft. The rainfall is more than fifty inches per annum at the higher altitudes, but there is a definite dry season from mid-December until mid-March.

The first distribution of seed of the 'Nyasa' Arabian strain took place in 1912, and by 1915 the crop amounted to about eleven tons of parchment. Later, in 1922, twelve government nurseries were established in South Bugishu, and a hand pulping machine was provided for free co-operative use. Planting of Arabian coffee was then actively encouraged, and by 1925 more hand pulpers were provided and the annual production rose to fifty tons of parchment coffee.

Owing to a lack of supervision, coupled with a period of misguided enthusiasm, there was considerable confusion during the next five years, but in 1930 control was re-established and private nurseries were prohibited. Only those who were amenable to instruction were permitted to plant coffee, and the 'Bugishu Coffee Scheme' was begun to control the preparation and marketing of the people's coffee. By the end of 1935 some 5,000 acres of Arabian coffee had been planted with a yearly production of 1,600 tons.

On account of the difficulty experienced in teaching illiterate Africans the single-stem method of pruning, the government evolved what they called the Uganda method of multiple-stem pruning for Arabian coffee. This consisted of topping the seedlings at an early age in the nursery and distributing the young plants a short while afterwards. Two uprights were then allowed to grow until the lower primaries showed signs of exhaustion, by which time they were pruned away and a third sucker was allowed to sprout from the base of the tree. From then onwards fruiting was restricted to the primaries of a succession of upright stems. It was found preferable to top the young plants a few months before they left the nursery rather than after they had been planted by the land-holder.

Surprisingly enough, and in spite of the multiple-stem system of pruning adopted by the advisory staff, attention was directed before the second world war towards a much closer spacing than the standard 8 ft. × 8 ft. which had hitherto been followed. This was considered possible and desirable during the first few years, because it led to increased yields, though it was admitted that alternate rows would have to be uprooted as the trees developed. In view of what has been discovered about the increasing value and bearing properties of old trees, the author would hesitate before he advocated such a close spacing for a permanent field of Arabian coffee.

During recent years *Albizia* shade trees have been found beneficial at the lower altitudes on Mount Elgon, and 'Kent's' coffee was introduced to replace the Nyasa strain. Under a Board of Control, the Bugishu Coffee Scheme deals with most of the crop of cherry coffee on a co-operative basis. The coffee is pulped and dried at a number of scattered centres and the product is concentrated at local curing works where it is hulled and prepared for export. Most of the technical difficulties of the scheme have been surmounted and coffee of good quality is produced. The chief difficulty is the regulation and computation of payments to the numerous peasant growers who sell cherry coffee to the pulperies long before sales of the cured bean can be concluded.

CHIEF PESTS AND DISEASES

Among the pests, the variegated coffee bugs *Antestia lineaticollis* Stal., and *A. faceta* Germ., are by far the most troublesome, more especially among scattered plots of African Arabian coffee where spraying controls are difficult to introduce. In fact, these bugs have been the deciding factor in many of the regions where Arabian coffee might otherwise have been successful, for they have forced a change-over to robusta coffee.

The berry borer, *Stephanoderes hampei* Ferr. has long been a pest in Uganda. The beetles and their larvae seriously affected Arabian coffee beans in the old days when the rubber trees overshaded the bushes, and they are very numerous in robusta plantings when the shade is too dense.

Hemileia vastatrix is the most common disease, but it is usually found attacking trees when they are weakened by cultural or environmental faults, or when the trees have over-borne their strength. It attacks all strains of Arabian coffee which are not of a resistant type, and it will occasionally appear on robusta coffee.

KENYA

THE BEGINNING OF THE INDUSTRY

At the time when coffee plantations were opened up in Uganda, Kenya was a very poorly developed country indeed. Outside the towns, and at a short distance from the railway, the roads were of the poorest kind and few and far between. The natives also were primitive and uneducated, and many of the tribes wore no clothes. A few Europeans with little knowledge of how to grow coffee opened up small estates of fifty to one hundred acres, which they planted with Arabian coffee of the variety *bourbon*, the seed of which was obtained from the French Fathers at the Roman Catholic Mission at Nairobi.

From those early days, the industry, despite the vicissitudes through which it has had to pass, has grown into one of the finest managed coffee industries of the world.

Because the industry developed mainly at high altitudes, the quality of the product was found to be good. Improved techniques of cultivation and preparation have given Kenya coffee world-wide renown for a raw product of high mild quality, unsurpassed except by the best Blue Mountain Jamaica coffee and some of the finest sorts from Mexico and the Central Americas.

By the early nineteen-twenties many estates had been developed in the environs of Nairobi, within a radius of twenty odd miles. Farmers, who had taken up land on the temperate higher plateaux and had always farmed their land according to European standards, adopted the practice of planting orchards of coffee as adjuncts to their mixed farming, and soon afterwards planters began exploring other districts with a view to trying out coffee.

Many localities to the east of the great rift valley were chosen for coffee, but the western areas were generally found unsuitable. There are a few excellent plantations on the floor of the valley, particularly at Solai near Nakuru. Kiambu and the nearby districts of Thika, Ruiru, Makuyu, Donyo Sabuk, Machakos, Kabete and lower Limuru are those where the Arabian coffee plantations have been most successful. There are plantations in the Nyeri district but Kiambu is the most favoured region.[13]

By courtesy of the United States Dept. of Agriculture, Foreign Relations Dept.

Note the wide spacing, the bare soil and the poor state of the trees in Brazil, following exhaustion, drought or frost damage. A number of seedlings are growing together. These have been stumped back to obtain new growth which has borne fruit and become exhausted. Note the die-back and the lack of shade

PLATE LXII

By courtesy of the Kenya Information Service

(*a*) A native grower interplanting shade trees in his coffee. Note the leggy trees which will soon be bent over to produce a multiple-stem growth

(*b*) Kilimanjaro mountain—a coffee grower dries his coffee. His modern type of house to the right and his old type—a bee-hive grass hut—to the left

PLATE LXIII

Until about 1925 few knew much about the needs of coffee and it was inevitable that mistakes were made. The highlands undulate with slopes at all aspects and soils of differing types, from altitudes of less than 5,000 feet up to 8,000 feet and more, and in general only the highest peaks receive a rainfall sufficient to make the environment ideal. Where the rainfall is sufficient the temperatures are often too cold. In general there are two wet seasons, with long and short rains, which amount to a fall of not more than forty to forty-five inches per annum leading to several flushes of flowering at different times of the year.

A great deal of the Kenya coffee is grown with a rainfall considerably less than fifty inches. Planters began with a close spacing of 6 × 6 ft., sometimes with no shade, and sometimes with *Grevillea* shade, and they pruned their trees to single stems, topping them at about five feet. Nursery plants were raised to produce leggy plants which were stumped back before planting them in the field, and no precautions were taken before the coffee was planted to safeguard the land against erosion. Clean weeding was practised.

On account of the short rainfall, and the methods used, much exhaustion and die-back occurred following the first good crops. *Hemileia* leaf spot disease was troublesome, *Antestia* bugs were often prevalent, and the Kenya mealy bug became a menace requiring the grease-banding of trees.

With low yields and high costs due to the fight against diseases and pests, and the following slump in the nineteen-thirties, failures were common and many planters had a hard time. Some had planted their coffee on soils which proved unsuitable, or at an altitude where the climate was too cold, and doubtless the industry would have come to an end as it did in Nyasaland, had it not been for the fact that the economy of the country had come to depend considerably on its coffee exports, so that it was necessary for the government to aid the industry without delay.

Research was begun in 1922. Parasites of the mealy bug were brought from Uganda and liberated in the coffee fields in 1938, thus successfully bringing this pest under control. The type of shade tree was altered, methods of cultivation improved, anti-erosion practices begun, methods evolved to overcome the other pests and diseases, and an advisory service inaugurated for the choice of localities and soils.

Overhead shade had long been a subject for controversy, though the question has in general been decided by the ruling that a light shade is required at altitudes below 5,000 feet, and none at all above 5,000 feet, except at high altitudes where cold nights require shade to protect the trees from low temperatures. Unshaded coffee grown near and above the 6,000 level is subject to what is called the 'hot and cold' disease, a slow bunched growth when the tips of the shoots are apt to shrivel and blacken. The favourite shade trees are *Albizia chinensis* (stipulata), *Grevillea robusta* and *Cordia holstii.*

Two of the most effective innovations in later years were those concerning the conversion from single-stem pruning to multiple-stem, and the mulching of coffee with cut grass, for these ameliorated the lack of sufficient rainfall. Seeds of a number of other varieties of Arabian coffee were later imported, including the Blue Mountain Jamaica and 'Kent's' coffee.

In spite of the trials and tribulations of maintaining such an industry in wartime, and because of steadier prices guaranteed by the Ministry of Food, the coffee industry found itself at last on a sure footing. An onlooker during these years must give full credit to the government, and in particular to the

research officers of the Kenya Agricultural Department, for the survival and present prosperity of the industry. Nevertheless, the hardiness and toughness of the Kenya planters in adversity must also be acclaimed, as also the co-operative spirit which has forged such a strong bond between them and the governmental advisory service.

Today, with the high prices that have been ruling during recent years, the Kenya coffee industry is in fine fettle, ready to resist any downward trend. Coffee planters throughout the world, especially those who are endeavouring to grow Arabian coffee in a similar environment, would do well to study the methods used in Kenya. There are few estates to equal the most up-to-date ones in Kenya, and the research and advisory services cannot be excelled.

The soils of Kenya are fertile enough, especially the red lateritic soils which are generally chosen for coffee, and since there is more land available for planting coffee, the only real hindrance to an expansion of coffee production is a growing shortage of labour.

NATIVE COFFEE INDUSTRY

With the strong development of native coffee-growing industries in the neighbouring countries of Uganda and Tanganyika, it was but natural that the natives of Kenya should want to grow coffee as well, as they became more educated and progressive. Many people wondered why the natives were forbidden to grow coffee until recent years. In this action the government was most wise.

As has been mentioned, there are very few areas in Kenya where the rainfall is sufficient for coffee without special techniques of cultivation and pest control. Nowhere are the climatic conditions suitable for robusta coffee, except perhaps in a very small region near Lake Victoria. The conditions were such that until there were sufficient staff and trained native agricultural instructors, it was impossible to aid the people in the choice of land, or to teach them the proper methods of culture, preparation and pest control. Had they been allowed to grow Arabian coffee haphazard, in scattered plots of their own choosing, many would have failed in their efforts.

The threat of the mealy bug pest was considerable, and this and other pests would have become overwhelmingly dominant had a multitude of neglected and abandoned plots of coffee become scattered about the country.

Instead, since staff has become available, natives have been licensed to grow coffee in suitable regions in grouped associations. They have received careful instruction, aided in every way by the installation of central pulperies and preparation centres, so that their industry has started on a sound basis. Every native grower is registered and every grower must conform to the proper standards of cultivation, preparation, and pest control. The native-grown Arabian coffee is of high quality but it is cured and marketed separately under a distinct mark.

Controls in no way differ from those pertaining to the European industry where compulsion is used to check erosion, and to combat pests such as borer beetles.

RESEARCH

Research has been concentrated at the Scott Agricultural Laboratories, Nairobi, and more recently at the Jacaranda Coffee Research Station, Ruiru.

Much information gained from the Kenya Research station is found in the appropriate chapters of this book.

CONTROLS AND MARKETING

The industry is represented by the Coffee Board of Kenya which publishes a Monthly Bulletin, and by the Coffee Marketing Board which concerns itself with the disposal of the crop. Coffee sampling and liquoring is carried out before sale, and auction markets are held at Nairobi and Mombasa.

Largely due to its high price during recent years, coffee has become the most valuable of all products exported from Kenya. On account of climatic variations the yields may vary considerably and this affects the bulk exports.

EXPORTS FOR RECENT SEASONS IN CWT. CLEAN COFFEE.[3]

1950/51	*1951/52*	*1952/53*
228,205	352,129	264,166

PRINCIPAL COUNTRIES IMPORTING KENYA COFFEE.

Country	*1950/51*	*1951/52*	*1952/53*
United Kingdom ...	87,942	86,475	103,495
Canada	32,955	27,526	5,593
South Africa ...	10,848	22,171	13,144
Australia	5,015	3,734	10,215
United States ...	18,114	23,221	2,938
Germany	24,711	51,620	93,269

AUCTION PRICES PER TON FOR KENYA.

GRADE A IN POUNDS STERLING.

	1950/51	*1951/52*	*1952/53*
Price range	426/648	240/603	308/518
Average price ...	£521	£484	£470

The estimated crop for 1953–54 was 11,000 tons, and the season opened with prices averaging £515 per ton.

Until the outbreak of war in 1939, Kenya coffee was marketed in two ways. The best quality coffee was very popular on the London market and it was the practice for planters to consign their coffee through agents to the London coffee brokers. This coffee was sold, usually by auction in Mincing Lane. It was ultimately found best to sell the low and medium qualities in Nairobi, either by auction or by private treaty. The local purchases were made by the Nairobi branches of established London coffee exporters who distributed it to world markets.

Because of shipping shortages during the war, controls became necessary in conjunction with the Ministry of Supply. A marketing committee was appointed in 1943 consisting of representatives both of planters and the trade, and in accordance with its recommendations, the Coffee Marketing Board was formed.

Legislation was enacted in 1946 making it compulsory for all coffee to

be sold through the Board. Contracts were made with the Ministry of Food which agreed to take up to 6,000 tons of Kenya coffee per annum at a price fluctuating within limits correlating to that for Colombian Medellin Excelso coffee in New York. Any balance left over was sold by the Board in the open market, including a minimum of 2,000 tons annually.

KENYA COFFEE STATISTICS BEFORE THE PERIOD OF HIGH PRICES.[18]

Year	*Exports in cwt.*	*Season*	*Average price*
			s. d.
1927	209,805	1927	(*a*) 116 7
1928	211,608	1928	106 10
1929	133,091	1929	115 6
1930	310,088	1930	77 0
1931	245,903	1931	74 0
1932	275,916	1932	85 0
1933	256,972	1933	64 0
1934	186,759	1934	60 3
1935	358,072	1935–36	61 2
1936	408,575	1936–37	73 2
1937	273,894	1937–38	58 0
1938	341,849	1938–39	70 7
1939	338,125	1939–40	87 10
1940	171,954	1940–41	(*b*) —
1941	247,738	1941–42	(*c*) 73 2
1942	246,676	1942–43	75 2
1943	156,132	1943–44	90 6
1944	148,655	1944–45	102 6
1945	149,297	1945–46	108 6
1946	191,823	1946–47	119 3
1947	212,076	1947–48	152 5
1948	285,874	1948–49	162 2

Notes.—1. (*a*) Onwards: London landed terms per cwt.
(*b*) No price given.
(*c*) Onwards: F.O.B. Mombasa price per cwt.

TANGANYIKA TERRITORY

EARLY HISTORY DURING THE GERMAN OCCUPATION

Before the 1914–18 war, coffee growing had become established in the

By courtesy of the Kenya Information Office

Pegging out a native coffee plot in Kenya

PLATE LXIV

By courtesy of the Kenya Information Services

Weighing-in native-produced cherry coffee at a pulpery

PLATE LXV

Usambara Mountains along the northern boundary, also on the slopes of Kilimanjaro and Meru mountains and in the Bukoba district west of Lake Victoria. At some of the Roman Catholic mission stations, for instance, in the Uluguru Mountains above the town of Morogoro, and at Old Moshi on the slopes of Kilimanjaro, the French Fathers had established coffee plants from seed brought from the island of Réunion about the year 1893. These were *Coffea arabica* var. *bourbon*, and it was from these mission trees that most of the seed was provided for the earlier planting of Arabian coffee.

Only a few plantations were sited in the Usambara Mountains, and these at about 4,000 feet, where, from a cursory examination of the vegetation, and because the south-east trade winds carried masses of rainclouds from the sea, it was thought that Arabian coffee would thrive. It promised well at first, but the light granitic soil ultimately proved its undoing. No sooner did the plantations begin to bear good crops than the trees were affected by exhaustion and die-back. British planters who bought the plantations after the war decided to uproot most of the coffee and grow tea instead.

As for the Kilimanjaro and Meru coffee areas, the German Government alienated the lower land on the south-eastern slopes of both mountains, and arranged that the Africans should inhabit the higher land between the European plantations and the forest belts. It was, in fact, a grave mistake on their part, for they gave the natives the best coffee land and an environment which was healthier from a European's point of view. At the same time they took away the land where the native food crops would have prospered best and where ample grazing would have been available for their cattle.

The cooler climate of the higher slopes, with a heavier rainfall and frequent mists, was not the best for the Chagga tribe of Kilimanjaro, a chocolate-coloured, intelligent, but delicate people who have suffered much from chest complaints since those days. It was not politic for them to be adjacent to the forest reserve, and astride all the mountain streams of clean water. They naturally cleared their own land of most of the trees, and very cleverly installed a network of irrigation furrows causing a complicated system of water rights that involves a great deal of legislation in the native courts. Erosion would have proceeded apace had not the British Administration tackled the problem soon after the war.

From an altitude of about 3,000 feet to 4,500–5,000 feet on both mountains, most of the fertile land was allocated freehold to German planters who planted the bourbon variety of Arabian coffee at a spacing of about 8 × 8 ft. under the shade of *Grevillea robusta*. In 1899, coffee to the value of £4,817 was exported.[19]

The coffee was pruned according to the single-stem method, and at some time before the first world war began, an Arabian variety known as Menado was imported from the Dutch East Indies and planted on Kilimanjaro. This had bronze tips to the young growths and a branching habit rather like the bourbon variety. It was found after the war among the bourbon coffee on a number of estates. About this time some of the Chagga people had begun to plant Arabian coffee in their higher-altitude country.

DISPOSAL OF EX-ENEMY PROPERTY

Of course the war interrupted coffee production, and as the estates were abandoned by their German owners they naturally fell into a state of neglect.

It was not until 1921 that the first auction of ex-enemy estates was held, and at that time there were not many Englishmen in the country with sufficient capital to invest in the resurrection of these properties. Greeks and Indians stepped in as opportunists and bought the coffee estates for a song, often buying blindly without having inspected the land. They found dwellings needing but little repair, and because much of the coffee had become heavily shaded, the weeds had not grown very thick. It took only a few years to bring the coffee plantations back into production, and by 1925 small fortunes had been made by resale to new owners. The British soon declared that no more land would be alienated except on lease, so these old German estates became the only freehold properties in Tanganyika Territory.

NATIVE-GROWN COFFEE

Meanwhile the Chagga people had gone ahead and planted hundreds of small plots averaging about half an acre each on the higher mountainside, and a coffee officer by name Patterson had been appointed to give them guidance. Full credit must be given to him for the confidence in his teaching which he managed to install among the scattered African planters. There was no fault to find in the way these coffee plots were cultivated and pruned, and since the Arabian coffee found its ideal environment between 5,000 and 6,000 ft, it grew healthily without being attacked by pests and diseases to anything like the extent of the coffee on the large estates at the lower altitudes. Patterson introduced the system of capping, so that the native single-stemmed trees were capped at knee, waist and breast high. Thus the trees were built up with strong frames, and bore most satisfactory crops without exhaustion. At that altitude there was no need for shade and the trees bore crops on the old wood.

The planters were afraid that if the Chagga people planted coffee extensively they would lose their local labour, and in their complaints to Government they had reason to fear that the poor quality of the African coffee might do harm to the good name that Kilimanjaro coffee had won on the London market. There were, indeed, serious faults to be found in the way the native coffee was prepared and sold, for the plots were so scattered that centralized pulperies and reception centres would have been difficult to install. Moreover, there were no funds to spare at that time. In practice the growers sold their coffee in parchment to Indian buyers, and there was no control over its quality. Parcels of clean dry parchment were mixed with dirty unwashed coffee and samples which were half dry.

The country was then held as a British Mandate and as the Government had no wish to forbid the cultivation of coffee by the natives, the author was posted to the Northern Province to improve the quality of the native coffee and thus meet the chief complaint of the European planters.

THE KILIMANJARO NATIVE PLANTERS' ASSOCIATION AND CO-OPERATIVE UNION

At first, it was necessary to fuse the native planters into a co-operative society, so the Kilimanjaro Native Planters' Association was born in the year 1925 at a meeting held in the Senior Commissioner's office attended by the coffee officer, the author and influential Chagga coffee growers. The growers agreed to bulk their parchment coffee for shipment to London and to share

the proceeds when the money came to hand, in accordance with their weighed deliveries. Regular delivery dates were arranged and the coffee parchment was graded before it was bulked for shipment to London through a local forwarding agent.

Grading was strict and carried out under the supervision of the Agricultural Department. Any coffee that was not dry was refused, and as dirty parchment was placed in a second grade, it was not long before all the coffee delivered was of first quality standard. London buyers began to know and look for the K N P A mark, since bulking standardized the quality, and the big consignments were attractive for re-export to the Continent. As a result of this, K N P A coffee began to win top prices, sometimes above those paid for the best plantation marks, and though the growers had to wait several months for their money they soon found their returns far exceeding those they had received from the wily Indian shopkeepers. Enthusiasm became widespread, the growers agreed to a levy on their coffee to provide funds, the name of their Association was changed to the Kilimanjaro Native Co-operative Union, and a European manager was employed to manage their affairs.

Of course there were teething troubles, but, at the time of writing, the Kilimanjaro Native Co-operative Union half owns the local curing works. Its estimated crop for 1954 is said to be 6,000 tons of clean coffee, which at the present price of £600 per ton will give £3,600,000. They have built a headquarters building in the town of Moshi at a cost of £150,000, and have become an example to follow for many other native co-operative societies which have since come into being in East Africa.

Similarly on Meru mountain the Wa-Arusha tribe also planted coffee and are in affiliation with the Kilimanjaro Association.

LYAMUNGU RESEARCH STATION

In the year 1933 a Coffee Research and Experimental Station was opened at Lyamungu in the Machame region at an altitude of 4,000 feet, to study the general problems of the industry and to raise the production per unit area. The many references in this book to the work of this station will give some idea of its value and service to the local coffee growers, and the new knowledge about coffee production which it has given to the world. Some of the first studies were based on research which had already begun in Uganda and Kenya, and in like manner some of the more recent research in India is now based on what is being done at Lyamungu. The station was sited at what one might call a medium altitude in the coffee-growing area, though on account of the difficulty in finding land it was placed rather too far west on the mountainside. This accounts for a rainfall of only sixty inches, and the fact that the rainfall is more erratic than records have shown it to be at higher altitudes on the south-eastern slopes.

However, the station's supreme value is in showing what can be done in an environment which one might say is a trying one and of medium value for Arabian coffee cultivation. On account of the warmer temperatures and erratic rainfall of the lower-altitude coffee lands, some of the larger plantations proved uneconomic of recent years, and have been bought by the native authorities to appease the land hunger, and give space for the ever-growing Chagga population. From a peak production of about 4,000 tons per annum soon after the first world war, the non-native production has

fallen to less than 2,000 tons, while the native production has more than doubled this amount and is still increasing.

SOILS OF THE NORTHERN PROVINCE

The soil on the slopes of Kilimanjaro is a red, volcanic, loamy-clay of considerable depth and fertility, while that of Meru is either of much the same kind, in which case it is satisfactory, or it is a volcanic ash-like but fertile soil which is too light for coffee. In this last region the water of the streams is the colour of tea, and there have been nutritional disorders causing yellowing of the leaves, berry fall and other troubles. Meru mountain is fifty miles west of Kilimanjaro, beyond hot, low-lying plains, and because the mountain is conical the area of high rainfall on the south-eastern slopes is smaller.

PRUNING SYSTEM

Following the findings of Lyamungu, much of the coffee in this Northern Province of Tanganyika has been converted from the single-stem to the multiple-stem pruning system. There is no doubt that the latter is sound below 5,000 feet where the crop is borne on young wood, but it is very doubtful indeed, whether it is a sound policy to adopt at the higher altitudes where the berry is borne mostly on the older wood.

BUKOBA COFFEE PRODUCTION

Many authorities have stated that robusta coffee is indigenous in the Bukoba district west of Lake Victoria. This, however, is extremely doubtful. The natives are an off-shoot of the Baganda people in Uganda to the North and their language is very similar. Since the Baganda have used robusta coffee for chewing, and had planted it near their huts before the days of the early explorers, it is very probable that the Bukoba people obtained plants from Uganda.

Only a comparatively narrow strip of land near the lake is suitable for robusta coffee production in the Bukoba district and this land is influenced by the moisture-laden winds sweeping across the lake from the south-east. Hence there are remnants of rain and swamp forest in some of the valleys near the lake shore.

Bukoba town is situated on a sand spit at 3,709 feet above sea level, but the land rises steeply from the lake shore to an undulating plateau nearly 1,000 feet above the town. The climate of the lake shore region is humid and warm. Temperatures are steady throughout the year and there are few months without some heavy showers of rain. The rainfall averages more than seventy inches per annum, so the climatic conditions are suited to robusta coffee.

The native people are intelligent but improvident, and the men leave most of the work for their womenfolk to do, hence coffee cultivation became an extra burden to the women, while the men took the proceeds.

Since the time the people settled in this area they have destroyed their forests and impoverished their land until most of the open country is now covered with short tufted grasses of little value for grazing. The soil is a chocolate and friable loam but absolutely dead and extremely infertile. Except for the wiry grasses, only the earth pea and a poor tuberous labiate will grow in the open spaces, and the people depend on their banana planta-

tions for food because these have been grown without respite on soil that has been constantly mulched. The coffee has been planted among the bananas in the only places where the soil is fertile enough for it to succeed. About ten to fifteen miles inland to the west, the rainfall rapidly diminishes until the country is covered by thorn bush except where swamps lie in the valleys. There seems no possibility of resurrecting the fertility of most of the land in the inhabited areas without enormous quantities of organic manures. Hence there is little chance of any great increase in coffee production in this area. Indeed, there is every likelihood of a decline as the people increase their numbers and must somehow win more food from an impoverished soil.

Robusta coffee was found in cultivation among the Bukoba people by Speke and Grant, and some of the trees are said to be one hundred years old.[19] The writer found a tree hidden in the banana plantations that had fallen over on its side at some remote period so that the stems rooted where they touched the ground and produced more uprights, like a banyan tree. This particular tree was a dome of growth covering a circle of ground more than thirty feet in diameter.

Arabian coffee of the bourbon variety was introduced to Bukoba district by Roman Catholic missionaries in 1896, where it is still grown intermingled with the robusta coffee. The robusta coffee is now very mixed, and has so many different forms that one must suspect hybridization with the Arabian coffee. The robusta coffee predominates and most of it is of the *nganda* variety, trained into dome-shaped bushes by bending over the upright growths to encourage more of them to sprout.

A period of intense activity began soon after the first world war, when a British administrator energetically encouraged the Bukoba people to plant more coffee. Unfortunately this occurred before the Agricultural Department had staff to send there, and the coffee was planted in a primitive fashion often spaced not more than a few feet apart. Extension work since then has concentrated on cutting out some of the closely-planted and unproductive trees, on introducing better pruning implements than an axe or a machete, and on the general improvement of the industry. It has been an uphill fight because of the extra burdens devolving on the womenfolk. The men are reluctant to work, and there is no doubt that the yield from the present plantings could be increased if the trees received proper treatment.

AMOUNTS AND VALUES OF BUKOBA COFFEE EXPORTED IN THE EARLY YEARS

Year	*Tons*	*Value* £
1912 ...	1,547	95,168
1913 ...	1,059	46,563
1917 ...	1,718	37,577
1918 ...	1,556	33,427
1919 ...	3,926	181,173
1920 ...	2,143	136,867
1921 ...	3,827	138,396
1922 ...	4,271	203,784
1923 ...	4,047	204,987
1924 ...	5,261	352,529
1925 ...	6,009	481,055
1926 ...	6,539	495,199
1927 ...	6,595	463,420
1928 ...	10,431	739,657

The Bukoba coffee is almost entirely produced by Africans, although the Arabian coffee is known to the trade as 'Bukoba Plantation' coffee to distinguish it from the robusta. There are less than half-a-dozen non-native holdings where Arabian and robusta coffees are grown. Prior to 1931, the native coffee was sold through a host of itinerant traders and small shopkeepers before it reached the bigger Indian merchants who dispatched and sold it to exporting firms at Mombasa. At every step a profit was made to the disadvantage of the producer, who was not above mixing a percentage of rubbish with the bean to increase the bulk weight. The coffee was harvested as cherry, which was dried on matting lifted off the ground as it is today, and then hulled in all manner of ways, sometimes by the aid of the non-native planters, sometimes in native-made hullers of wood and tin, or by pestle and mortar, or by grinding the pericarp of the dried cherry to pieces on outcrops of rock. The conditions of sale and export were most unsatisfactory.

In 1930 the author was sent to Bukoba to begin inquiries to see how the quality of the coffee might be improved. It was not easy to overcome the vested interests of the buyers at all levels since the producers and the smaller men were in debt to those higher up the scale on account of trade goods received. The only immediate improvement possible was the promulgation of a Coffee Grading Ordinance with provision made for the compulsory grading of all coffee before it left the port. This was started and became the example on which the Uganda Grading Ordinance was based.

More recently the control of the Bukoba coffee production has passed to a Native Production Board to obtain more co-operation among the growers and thus control the preparation and sale of their coffee. A Coffee Industry (Registration and Improvement) Ordinance has been in force since 1928 to provide for the annual registration of all coffee plantations and nurseries in Tanganyika Territory, also the registration of marks, and the licensing of all dealers. This Ordinance was preceded by the issue of the Plant, Pest and Disease (Coffee) Regulations which provided for the prevention and eradication of pests and diseases to which coffee is liable.

Statistics of coffee production for the Territory during recent years show that the Bukoba crop has remained static except for seasonal fluctuations, confined as it is to the area planted with bananas, and dependent on the strength of the native womenfolk. The correct proportion of Arabian Coffee can now be given.

LAKE PROVINCE RETURNS—BUKOBA AND BIHARAMULO

Year	*Robusta*	*Arabian*
	Tons	Tons
1948 ...	4,998	1,140
1949 ...	5,200	2,087
1950 ...	6,420	1,625
1951 ...	6,650	2,134

NORTHERN PROVINCE RETURNS

Year	*Native*	*Estate coffee*
	Tons	Tons
1949 ...	4,225	2,246
1950 ...	5,455	1,619
1951 ...	4,890	2,122

OTHER COFFEE AREAS IN TANGANYIKA

After the first world war, land was alienated on leasehold in several parts of the Southern Province, e.g., at Mbosi near Mbeya, and near Tukuyu, at Njombe, Lupembe and Dabaga. Among those who settled there were a number of Germans who returned to the Territory, and some who found their original estates in the Northern Province had been sold. Natives had also begun planting Arabian coffee in the foothills of the Livingstone Mountains near Tukuyu. Many of the settlers opened up land for coffee planting in areas that were thought favourable. The author toured this area in 1928 and discovered very little hope of success in the majority of cases.

The rainfall was erratic, unevenly spread and often insufficient; the winds were keen, the night temperatures low with frosts occurring in the valleys; the situations chosen were wanting in many respects, with soils that were sometimes shallow and superimposed on layers of gravel or volcanic ash. The local vegetation and plant associations were such as to offer poor promise of success. Many of the hopes expressed by the planters were based on the health and growth of a few old coffee trees at a mission station.

It is of course possible, even in an area entirely unsuited to coffee production, to rear and cosset a few plants in a shaded garden so that the trees make an astounding growth. Such trees can be given every care and ample moisture supplies if only from household waste. They can be mulched, manured, shaded and tended with such care that they succeed willynilly—misleading in a region where a large estate could not prosper. Only one thing favoured coffee in the Southern Province at that time. It was entirely free from the leaf rust disease *Hemileia vastatrix*, though during recent years this has affected the coffee and spread throughout the area. In the Mbeya area, however, a red spider was much in evidence, giving the leaves and the plantations a red appearance. Often they occurred in association with infestations of nut-grass (Cyperceae), which indicated uneven rainfall and waterlogging. Time proved that coffee could not succeed on more than a few favoured estates. Much of the coffee has since been uprooted in favour of tea or pyrethrum planting.

Settlers have also planted coffee in the Northern Province to the west of Arusha, and in the Ngorongoro Crater area. Results are uncertain and there can be no promise of widespread industries where only favoured estates can succeed. The rainfall is too short and erratic over most of this region. Native coffee planting has also been encouraged in the North Mara region east of Lake Victoria, and in the Biharamulo district just south of the Bukoba district, where again the rainfall and temperatures are not ideal for Arabian coffee. Indeed, one might sum up the potentialities by saying that increased coffee production in Tanganyika is limited by the amount of land available in the regions suited to coffee growing. These are comparatively small and comprise the south-eastern slopes of Kilimanjaro and Meru mountains, and a narrow strip of land in Bukoba district bordering Lake Victoria.

THE MARKETING OF TANGANYIKA COFFEES

During and since the war a large proportion of the coffee was marketed under agreements with the Ministry of Food until after 1952. Coffee sales at auction markets have since been arranged for the Northern Province, where a choice may now be exercised. Coffee may either be sold at Moshi, or be

railed to Mombasa in Kenya for sale there. Most of the Bukoba coffee is shipped across the lake to the Uganda Railway, and then railed to Nairobi or Mombasa for auction sale in Kenya.

METEOROLOGICAL FIGURES, CENTRAL AND EAST AFRICA

The following figures of rainfall, and of maximum and minimum temperature averages throughout the months of the year, are given to show the rainfall spread and the temperature ranges in some of the coffee-growing regions of Central and East Africa. Mean figures are apt to be misleading, since they hide extremes and the erratic years. Despite this, it is possible to see that the returns from some stations are outstanding. Note the evenness of the figures for Bukoba, for instance, and the narrower limits between maximum and minimum temperatures. Compare the rainfalls and the periods of drier weather between Bukoba on the one hand and the Nyasaland stations, or even those in Kenya, on the other. The rainfall is surprisingly short where coffee is grown in many of the areas of East Africa. (*See* Tables.)

MADAGASCAR AND THE SURROUNDING FRENCH ISLANDS

HISTORY

About the time that the Dutch were founding their coffee industry in the East Indies, the French were founding theirs in Madagascar and in some of the surrounding islands, in particular Réunion. It is natural, therefore, that the two should have taken a close interest in each other's ventures. One reads, for instance, that the French at one time favoured the robusta coffee then known as *Coffea congensis* var. *charlotti*, and that seeds of this coffee were taken from Madagascar by the Dutch. Later, when it was proved that the so-called 'quillou' coffee was resistant to the leaf disease, and a better yielder than *C. congensis*, seeds were imported by the French from the East Indies.

The original importation of seed was, however, of the Arabian kind direct from Arabia, and this was planted in Réunion. Much of it proved to be *C. arabica* var. *bourbon*, and this was chosen by the French for propagation. From here, indeed, the well-known bourbon coffee travelled about the world and reached East Africa via the French mission stations.

It is necessary to repeat that in those days little was known about the needs of coffee and the proper way to cultivate it, so mistakes were made which led to failures and disappointments. It is understood, therefore, that coffee is no longer produced for export in Réunion, and that Arabian coffee is not particularly favoured in Madagascar.[4]

The islands are somewhat south in latitude, and temperate environments are to be found at much lower altitudes. It is curious, therefore, that, despite their preference for warmer temperatures, the robusta coffees have made progress at the expense of Arabian coffee.

Present-day production is, therefore, largely composed of robusta coffee, and a great deal of work has been done to breed and select forms of good quality and yield adapted to the local environments. The earlier liking for *C. congensis* was not entirely relinquished, for it has been crossed and re-crossed with the 'quillou' coffee (which closely resembles *C. canephora* var. *nganda*)

RAINFALL IN INCHES

IN OR ADJACENT TO THE COFFEE AREAS

Country and District	*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*No. of years*	*Aver-age*	*Reference*
Nyasaland.															
Blantyre	1·50	3·40	7·30	11·60	8·40	7·00	1·80	0·70	0·40	0·40	0·10	0·30	25	42·90	(4)
Zomba	1·55	5·30	10·60	11·40	10·40	8·90	3·80	1·10	0·54	0·32	0·42	0·35	30	54·68	(4)
Uganda.															
Entebbe ...	2·57	3·57	6·27	10·08	9·60	4·77	3·00	2·95	2·95	3·74	5·17	4·57	50	60·24	(3)
Kampala	1·82	2·40	5·07	6·91	5·77	2·89	1·76	3·42	3·62	3·82	4·80	3·90	15	46·18	(3)
Masaka ...	2·20	2·54	4·59	7·17	6·82	1·87	1·41	2·07	3·42	3·87	3·85	3·32	43	43·13	(3)
Mubendi ...	1·35	2·67	4·32	5·79	4·38	2·33	2·28	4·76	5·24	6·53	5·18	2·56	?	47·39	(2)
Fort Portal ...	1·02	2·53	5·49	7·20	5·16	2·99	2·25	4·50	7·30	8·84	6·77	2·87	?	56·92	(2)
Hoima	1·07	3·06	4·86	6·65	6·48	3·62	4·22	5·85	7·02	7·63	5·81	2·56	?	58·83	(2)
Kenya.															
Nairobi (Kabete)...	1·52	2·49	4·94	8·31	6·23	1·82	0·63	0·95	1·16	2·14	4·33	3·37	17	37·89	(3)
Nakuru	0·66	1·54	2·57	4·99	4·49	3·33	4·40	4·06	2·67	2·17	2·48	1·21	37	34·57	(3)
Kiambu	1·47	1·88	4·79	9·58	5·90	2·19	0·99	1·10	1·36	2·54	5·43	3·24	45	40·47	E.A.Met.D.
Ruiru	1·10	1·28	3·80	7·99	3·97	1·39	0·59	0·98	1·01	2·56	4·96	3·09	26	32·72	,, ,, ,,
Kitale	0·77	1·50	2·30	5·89	6·90	5·07	6·73	6·71	3·89	2·43	2·01	1·27	8	45·47	1948
Tanganyika.															
Bukoba	5·88	6·52	10·61	13·41	12·62	3·66	1·44	3·23	3·86	4·89	6·34	7·30	24	79·76	(3)
Machami ... ... (Kilimanjaro)	2·30	3·80	4·70	25·80	20·00	8·40	5·00	2·30	1·00	1·80	2·30	2·70	10	80·00	(4)
Lyamungu ,, ...	1·12	1·90	4·77	19·42	17·83	4·43	1·91	1·16	1·44	1·36	2·15	2·56	12	60·05	(5)
Kibosho ,, ...	0·00	2·72	6·83	40·31	15·77	5·45	1·68	0·98	0·90	0·20	4·88	0·30	1	80·02	(4)
Old Moshi ,, ...	1·65	3·90	4·65	17·73	12·70	1·85	2·16	1·10	0·91	1·10	3·54	2·56	13	53·85	(4)
Kilema ,, ...	2·35	0·12	14·15	22·98	8·60	1·94	2·38	0·00	1·68	2·92	6·67	1·76	1	65·55	(4)
Arusha (Meru) ...	2·91	4·17	7·64	13·42	6·30	1·10	0·75	0·43	1·30	1·50	5·51	3·42	9	48·45	(4)
Sakarre (Usambara)	3·80	3·50	3·50	13·70	14·30	5·80	4·40	3·80	2·70	4·10	3·70	3·30	4	67·40	(4)
Amani ,, ...	3·31	3·07	6·75	14·19	13·36	4·79	3·86	3·95	4·01	6·09	6·63	6·53	32	76·54	(3)
Mbeya	7·61	6·43	7·20	4·49	0·72	0·06	0·03	0·08	0·08	0·55	2·29	5·34	13	33·88	(3)

MEAN MAXIMUM DAILY TEMPERATURES

IN DEGREES FAHRENHEIT

Country and District	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	No. of years	Reference
Nyasaland.														
Zomba ...	80·5	80·0	79·2	78·4	75·4	72·4	72·0	76·0	80·6	85·8	85·4	81·4	25	(4)
Uganda.														
Entebbe ...	80·1	79·7	79·2	78·0	77·0	76·7	76·0	76·9	78·3	79·3	79·0	78·7	15	(3)
Kampala ...	82·7	82·4	80·9	78·9	77·6	77·4	77·0	78·2	79·9	81·0	80·4	80·5	15	(3)
Masaka ...	80·7	80·8	79·4	77·7	76·2	76·2	76·2	77·2	78·4	79·0	78·9	78·7	14	(3)
Mubendi ...	80·9	80·8	79·1	80·1	80·4	80·5	80·3	80·4	80·2	80·0	78·3	78·7	8	(4)
Fort Portal	80·8	81·2	80·5	81·0	79·1	78·2	72·2	78·4	76·7	77·8	78·7	79·2	13	(4)
Hoima ...	88·5	89·3	86·1	84·4	82·0	82·2	79·3	80·5	81·5	82·0	83·8	84·1	?	(2)
Kenya.														
Nairobi ...	76·8	78·9	77·5	74·7	72·2	70·1	68·7	69·9	74·8	76·4	73·9	73·7	15	(3)
Nakuru ...	82·6	84·5	83·5	80·2	78·1	77·2	75·0	75·7	78·8	79·3	78·3	79·4	15	(3)
Kiambu ...	80·3	82·1	80·6	77·1	74·5	71·4	70·9	72·1	77·6	78·4	76·5	76·6	10	E.A.Met.D.
Ruiru ...	79·8	82·7	80·4	77·7	75·0	73·2	72·1	72·2	77·5	79·0	75·8	75·8	7	,, ,, ,,
Tanganyika.														
Bukoba ...	78·8	78·6	78·8	77·0	76·8	77·7	77·4	77·0	78·8	79·5	79·0	78·3	19	(4)
Lyamungu	82·4	83·5	80·2	74·5	71·1	69·1	68·9	70·3	74·5	78·1	80·6	80·8	4	Ann. Repts.
Old Moshi	84·4	86·2	83·5	77·2	73·8	72·0	71·4	73·0	75·9	81·3	82·6	82·8	9	(4)
Arusha ...	84·2	84·9	84·6	79·2	73·2	71·6	71·6	73·8	77·5	82·6	83·8	83·7	9	(4)
Amani ...	81·2	82·7	80·8	76·8	74·5	72·4	70·5	70·7	72·7	75·2	77·7	79·5	5	(3)
Mbeya ...	73·0	73·3	72·8	72·1	71·3	69·9	69·9	71·9	77·0	79·7	79·1	75·4	14	(3)

MEAN MINIMUM DAILY TEMPERATURES

IN DEGREES FAHRENHEIT

Country and District	*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*No. of years*	*Reference*
Nyasaland.														
Zomba ...	63·9	63·4	62·3	60·1	56·0	52·7	51·5	53·3	57·6	62·4	64·8	64·0	25	(4)
Uganda.														
Entebbe ...	63·7	64·3	64·5	64·9	64·6	63·3	61·8	61·8	62·3	63·3	63·6	63·2	15	(3)
Kampala ...	64·5	64·6	64·2	63·8	63·5	62·9	61·8	61·4	61·8	62·6	63·0	63·2	15	(3)
Masaka ...	62·0	62·4	62·2	62·1	61·7	61·1	60·0	60·3	60·6	61·3	60·9	60·6	14	(3)
Mubendi ...	62·8	63·4	64·2	63·6	63·0	63·4	63·0	62·8	62·3	62·5	63·1	62·3	8	(4)
Fort Portal	55·9	56·9	58·2	58·7	57·3	56·4	57·7	57·4	56·4	56·0	57·0	54·9	13	(4)
Hoima ...	62·8	64·5	64·2	64·2	63·5	62·8	62·3	62·1	62·0	62·2	62·5	61·5	?	(2)
Kenya.														
Nairobi ...	54·0	55·2	56·8	57·7	56·3	53·5	51·5	51·6	52·2	54·7	56·0	55·1	?	(3)
Nakuru ...	47·9	49·2	50·7	52·5	52·9	51·0	50·9	49·8	47·7	48·2	49·3	48·8	?	(3)
Kiambu ...	53·9	55·8	57·2	58·8	57·1	54·6	51·8	52·2	52·7	56·0	57·2	56·1	10	E.A.Met.D.
Ruiru	54·4	54·3	56·7	59·5	58·6	54·8	52·9	53·5	53·8	55·8	57·7	55·8	7	,, ,, ,,
Tanganyika.														
Bukoba ...	61·9	62·2	62·6	63·1	63·1	62·2	60·6	60·4	61·3	61·2	61·5	61·3	19	(4)
Lyamungu	58·3	58·6	59·9	60·4	59·7	57·6	56·0	54·9	55·2	56·4	57·6	57·5	4	Ann. Rpts.
Old Moshi	63·5	64·0	64·4	62·6	61·3	59·2	57·7	57·7	58·3	60·1	61·7	62·8	9	(4)
Arusha ...	56·5	58·8	59·2	60·4	59·0	55·8	54·1	54·5	55·6	57·0	58·8	57·6	9	(4)
Amani ...	64·1	63·7	64·3	64·2	63·0	59·8	58·4	58·1	57·7	59·3	62·6	63·6	5	(3)
Mbeya ...	57·1	57·1	56·8	55·3	52·1	48·0	46·0	48·2	51·5	54·3	56·1	56·9	14	(3)

to improve the yield. The planting of robusta coffee of various forms was begun about 1905.[4] Liberian coffee is also cultivated to a small extent.

A study has been made of different methods of preparation in an effort to avoid a prolonged fermentation process and quicken the production of dried bean. Some producers have preferred a treatment with dilute soda lye to fermentation, for they believe that this improves the quality and liquor.

MADAGASCAR PRODUCTION OF CURED COFFEE

Year	*Production*	*Export*
	Metric tons	Metric tons
1949 ...	29,228	25,625
1950 ...	30,726	44,880
1951 ...	26,092	30,519
1952 ...	41,345	41,811
1953 ...	—	36,233

Notes.—1. The above figures were supplied by courtesy of the Commercial Counsellor of the French Embassy, London.
2. It would appear that stored coffee was included in the exports as price values increased.

PORTUGUESE AFRICAN COLONIES

PORTUGUESE EAST AFRICA

There are no records of any significant export of coffee from Portuguese East Africa. For the most part the territory is unsuited to coffee cultivation. It is comparatively low-lying without an even, sufficient distribution of rainfall. There are mountainous areas to the north, but wherever the altitude is high enough to give sufficient rainfall, the temperatures in season are probably too cold.

PORTUGUESE WEST AFRICA (ANGOLA)

Coffee is grown in the north-western section of the country, mostly north of the Benguela railway and in the coastal hinterland where rainfall and temperatures are suitable for the cultivation of robusta coffee. Elsewhere to the south and east, the climate is too dry or irregular. Temperatures are too hot in season in the lowlands and too cold in season in the highlands for a coffee industry to develop.

Even so, coffee was listed as the product of chief value and importance in 1952, despite a considerable reduction in value from that of the previous year. Coffee was the basis on which the large and unprecedented favourable balance of trade with the United States of America was built up in 1952.[20] It was the only important product in respect of which the Government's policy of directing exports to the dollar area survived. Some 20,260 tons of the 40,999 tons total were shipped to the United States in 1952. Other important buyers were, in order of importance, the Netherlands, Portugal and the United Kingdom.

By courtesy of the French Commercial Attaché, London

Young Arabian coffee being cultivated in the French Cameroons

PLATE LXVI

By courtesy of the Agence économique des Colonies

Robusta coffee at Divo, in the Ivory Coast

PLATE LXVII

EXPORTS FROM ANGOLA

METRIC TONS

1951	*1952*
64,432	47,661

BELGIAN CONGO

DISTRIBUTION OF THE SPECIES

Robusta coffee, which has been cultivated by the people of Angola for a very long time, is now becoming one of the most important crops of the Congo, though, since 1920, a good deal of Arabian coffee has been grown.

Coffee of one kind or another is now grown almost everywhere in the country; the Arabian coffee is found at the cooler altitudes of Kivu, L'Ituri and Kibali, but principally in the territory of Ruanda Urundi. The mountains of Ruanda Urundi, with their many streams, form the watershed of the Kagera River which flows along the boundary between Bukoba district in Tanganyika and Ruanda Urundi in the Belgian Congo. The Kagera river flows into Lake Victoria and is, in fact, the real source of the River Nile.

Thus Arabian coffee is found on the high ground and escarpments following the line of the lakes to the east, from the northern part of Lake Tanganyika, and continuing northwards, west of the Uganda border.

Robusta coffee is grown in the other parts of the territory though chiefly in the central and northern half.

Coffee is cultivated both by Europeans and by the native peoples, and wherever a native industry exists it is brought under close European guidance and supervision. Arabian coffee is cultivated with success at altitudes of 4,000 to 5,000 feet, where the temperatures vary between 64° and 72° F. and the rainfall is 40 to 60 inches per annum. Robusta coffee has a warmer climate at altitudes of not much more than 2,500 feet, where the temperatures vary between 70° and 80° F. It is believed that robusta requires more rain than Arabian coffee because the cropping periods are prolonged.

Shade is regulated to the minimum considered necessary to ensure a maximum flower production and economic crops. It is considered important to provide windbreaks.

The whole system of cultivation, including seed sowing, planting, pruning and maintenance, follows fairly closely the enlightened methods now practised in East Africa. Spacing depends on the species planted and the type of pruning adopted. For Arabian coffee the spacing is generally from $6\frac{1}{2} \times 6\frac{1}{2}$ ft. to 8×8 ft. (2×2, or $2{\cdot}50 \times 2{\cdot}50$ metres), and for robusta coffee 10×10 ft. to $11\frac{1}{2} \times 11\frac{1}{2}$ ft. (3×3 or $3{\cdot}50 \times 3{\cdot}50$ metres). Both single-stem and multiple-stem systems of pruning are being followed. Multiple-stem pruning is said to bring an increase in yield of 200 kg. of marketable robusta coffee per hectare per annum, calculated over a five-year period.[16]

As in other coffee-growing countries, trials of different systems of cultivation are constantly being made and introduced by plantation owners. Restriction of the provision of land for coffee growing by Europeans in the

Congo has forced owners to think of ways and means to rejuvenate their coffee.[5] This coffee is either being grown in a manner which fosters exhaustion, or the environments leave much to be desired. It does not seem to be appreciated that a tree should become more valuable as it grows older.

Mention has been made of what is called periodic or perpetual rejuvenation. Periodic rejuvenation means the interplanting of young coffee between older trees in holes prepared some while beforehand and filled with organic material. This is said to benefit the older trees which are pruned to make room for the younger trees planted between them until these in turn begin to bear. Perpetual rejuvenation is merely the stumping of alternate rows so that half the plantation is bearing while the other half is making new growth. The practice leads to close planting, and there are many other reasons why the system cannot be recommended. It would be impossible to practise such methods, for instance, if adequate shade were present. The shock of stumping to the root system is considerable, and there may be competition for inadequate moisture supplies, with weakened stamina and poor yields in consequence. The incidence of pests and diseases would be encouraged.

In 1911, an experiment station was opened near Stanleyville to study the various problems that had arisen, and a great deal of seed selection of robusta coffee has been carried out. Mother trees of some of the best forms have been selected and their progeny tested for yield and quality. Strains are thus being procured adapted to the different environments found in the Belgian Congo.

The coffee is prepared by both the dry and wet methods, the former applied mostly to robusta coffee and the latter to the Arabian kind. The 'Raoeng' pulping machine which rubs away the mucilage covering the parchment so that it may be dried and prepared without fermentation is used by some of the planters. All coffee for export must first be submitted to regional delivery and curing centres for examination and sorting for grade and quality. Only the best quality coffees are exported, and these are bulked and made up into grades in accordance with the requirements of the importing countries.

EXPORT IN METRIC TONS (1,000 kg.)

FROM THE BELGIAN CONGO AND RUANDA URUNDI

Year	*Tons*
1920	113
1930	1,537
1935	13,161
1939	19,898
1945	24,515
1946	19,555
1947	24,355
1948	30,545
1949	31,445
1950	33,389
1951	35,393
1952	30,901

The figures show a steady increase in production, with fluctuations in accordance with good and bad seasons.

DESTINATION OF BELGIAN COFFEE 1952
METRIC TONS

Destination	Ex. Belgian Congo		Ex. Ruandi Urundi
	Robusta	*Arabian*	*Arabian*
Belgium	9,572	948	2,105
Germany	3	1,026	—
United Kingdom ...	1,609	260	193
Italy	1,057	532	—
Norway	1,166	—	—
Sweden	—	96	70
America	2,122	619	8,204
Australia	—	—	55
Kenya Uganda . .	12	170	37
Sudan	781	2	—
South Africa ...	6	105	9
Other countries ...	34	48	57

WEST AFRICAN TERRITORIES
(under British Guidance)

REGION COVERED

Mention is made of those countries for which exports have been recorded and where a significant interest in coffee production has been taking place.

In the warm pluvial region along the whole of the coastal hinterland, wherever the rain forests extend and the soil is fertile and well drained, the area can be said to be suited to the cultivation of Liberian and robusta coffees. Indeed, it is along the west coast that various forms of these two species are indigenous. Perhaps because of this, and the fact that these coffees were low-priced before the unprecedented high values of recent years, very little coffee had been gathered or grown for export purposes prior to the nineteen-fifties. Interests lay chiefly in the production of cocoa and palm oil, as they do today, and only small surpluses above the quantity required for local consumption were exported when prices temporarily improved.

The further one penetrates east and north from the coastal and equatorial regions, the drier and more arid do these countries become. Nowhere is there an ideal region of temperate climate with a heavy, even rainfall where an Arabian coffee industry could develop with success. The coffee that is exported, has been produced by African peasant farmers.

Latterly, because of the high prices which have been ruling since 1949, an increasing interest in coffee culture has developed, and governments have

thought it wise to encourage coffee planting if only to diversify the industries on which these countries depend.

SIERRA LEONE

In 1952 the Sierra Leone Produce Marketing Board controlled the price and export of coffee though the amount produced was negligible.[3] In fact, exports practically ceased for a while because the price offered was considerably less than that being paid over the French border, where the product found its exit. In 1953, the product was decontrolled and normal exports were resumed.

Better prices in 1954 gave considerable encouragement to coffee producers so that more than 1,000 tons were exported during the first ten months in comparison with only 1 ton during the same period of the previous year.

By the middle of the year planting was in progress in many districts and the crop was rapidly gaining in popularity. A widespread effort has been made to site and peg out plantations in suitable localities. At the same time, the older plantations have been cleaned up, since, in the rapid development of a new industry by indigenous, semi-literate people, it is important to proceed from the start along proper lines.

GOLD COAST

In early 1954, the Agricultural Produce Marketing Board set up a scheme —similar to that of the Cocoa Marketing Board—for the buying of coffee. A number of licensed buying agents were appointed to accept the crop at buying stations at minimum prices which were, in the beginning, £252 per ton for coffee known as Type I, and £242 13s. 4d. per ton for Type II.

Coffee grading started as follows: (1) 'Superior quality—Type I', defined as coffee free from extraneous matter and consisting of clean dry beans free from mustiness and containing less than 20 per cent by count of defective beans inclusive of not more than 8 per cent by count of black beans; (2) 'Fair Average quality—Type II', defined as coffee free from extraneous matter and consisting of clean dry beans free from mustiness and containing not less than 20 per cent, but more than 25 per cent by count of defective beans inclusive of not more than 8 per cent by count of black beans. The grading marks were 'Robusta Type I' or 'Robusta Type II'.

From January to March 1954, 320 tons of coffee were purchased of which 183 tons were exported.

Coffee planting is increasing and is encouraged by the sale of seedlings raised by the Agricultural Department at a price of ½d. per plant, or 3s. 0d. per 100 plants. The industry is wholly in the hands of native growers.

WEST AFRICAN TERRITORIES
(under French Control)

REGION COVERED

In general, the same remarks apply to the regions under French Administration as to those under British protection, for there is a similar moist and

By courtesy of the Belgian Commercial Attaché London

Robusta coffee tree at Medje in the Province Orientale, Belgian Congo

PLATE LXVIII

By courtesy of the French Commercial Attache, London

Coffee planted among coconut palms at Niaouli, Dahomey

PLATE LXIX

warm region along the coastal belt, merging into semi-arid and desert regions beyond the immediate hinterland.

There is, however, land in the French Cameroons where Arabian coffee is grown. A small quantity of Arabian coffee is also produced in French West Africa, e.g., in French Guinea, where at Sérédon, in contrast to the equatorial climate of Bingerville on the Ivory Coast, there are two clearly defined seasons—a long wet season followed by a short dry one—which lead to a well-marked period of flowering.

Again generalizing, the coffee industries of French West Africa are much older than those in British West Africa. Here and there plantations have been started by Europeans, and on the Ivory Coast a great deal of research has been done in the selection and propagation of choice forms of Liberian coffee which do not necessarily grow true from seed. It is here that the natives propagate much of their coffee by inserting large hard-wood cuttings in the ground.

As in many other regions where the natives have grown their coffee in small plots and given them scant care while prices were low, pests have become troublesome, especially several kinds of borer beetles. The higher prices of recent years have brought new interest, and better methods of cultivation have been introduced so that the exports of coffee from all these countries are soon expected to increase as new plantations begin to bear.

FRENCH WEST AFRICA

The vast area of French West Africa includes French Guinea, Togo, the Ivory Coast and Dahomey, and since the Ivory Coast is adjacent to Liberia, the home of Liberian coffee, it is natural to find many differing forms and species of coffee. Liberian coffee is grown adjacent to robustas, and several forms of coffee are labelled as excelsa.

In fact, on the Ivory Coast there is such a mixture of coffee that it is difficult to separate it into homogeneous parcels for export.[4] As in French Guinea attempts have been and are being made to localize the cultivation of each variety. In French Guinea, robusta, Liberian and forms of excelsa are grown, and on the Ivory Coast matters are complicated by the presence of Liberian forms with small-sized fruits and beans known locally as 'Gros et Petits Indéniés'.

In Dahomey, production is based mainly on robusta coffee, and wherever robusta is grown the form known as 'quillou' is the one chiefly favoured.

FRENCH CAMEROONS

Very little attention was given in the past to the way in which the Arabian coffee was planted and cultivated. Grown by the indigenous peasant people, often in the neighbourhood of their huts and villages, the coffee was spaced too closely, often on unsuitable soils, which were seldom cultivated or weeded. No pruning was done and pests and diseases became very troublesome. It is only of recent years that instruction has been given in proper methods of cultivation, and the planted areas cleaned up.

The areas of coffee cultivation in the Cameroons are now divided into zones, the high plateaux being reserved for Arabian, and the central region for robusta coffee.

FRENCH EQUATORIAL AFRICA

Mainly robusta coffee is grown in Equatorial Africa, and mostly of the 'quillou' kind. To the north-east in the region of Lake Chad, *Coffea excelsa* was found to be indigenous.

THE PRODUCTION AND EXPORT OF COFFEE DURING RECENT YEARS IN METRIC TONS

Year	*French West Africa*	*Togo*	*Cameroons*	*French Equatorial Africa*
Production				
1949	46,639	1,968	8,060	4,109
1950	45,279	1,382	8,246	4,335
1951	53,334	3,264	10,618	2,308
1952	67,090	2,407	8,307	2,246
Exports				
1949	63,742	2,029	8,250	2,684
1950	57,739	1,177	7,653	4,678
1951	62,925	3,432	8,682	4,249
1952	71,381	2,593	9,238	4,965
1953	56,371	2,843	9,626	2,728

Note.—The above figures were supplied by courtesy of the Commercial Counsellor of the French Embassy, London.

Unfortunately, it has been impossible in this chapter to investigate fully the history, research, environments and methods of cultivation of coffee in Belgian, Portuguese and French territories. This would possibly have meant repetition, for there is mention here and there in other chapters of various matters of interest. What is certain, however, is that experience and research have automatically propelled all the countries in Africa along similar lines of progress. Some of our own research, e.g., that on the berry disease of coffee, also the vegetative propagation of coffee, and the selection of ecotypical strains, has been confirmed by research workers in Belgian and French territories. References given in the selected list should give any additional information desired.

Liberia and the small Spanish possessions where coffee is grown to a limited extent have also been omitted for the same reason. Even South Africa has grown and is growing coffee in a few favoured localities, and if the whole story were told in detail, then this book would grow to double its present length.

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Chapter XVI

COFFEE PRODUCTION IN ASIA AND THE ANTIPODES

General

Wherever original supplies of seed from Arabia have been sown there appears to be an infinite mixture of forms within the breed. That is to say that although one coffee tree may look very similar to another, the progeny may differ on account of a rearrangement of the genes. There appear to be potentials that become less in course of time when one particular form is selected and cultivated in a new region, where many influences including a natural, unconscious, or deliberate selection maintained over a period of years, seem to cause a strain to settle down and become peculiar to one country.

There are certain outstanding characteristics of which we have become aware, such as the green-tipping and angular upright branching of var. *bourbon*, and the bronze tipping and horizontal branching of var. *arabica*; also the resistance to *Hemileia* leaf spot disease exhibited by the 'Kent's' variety which originated in India.

Although these characters appear linked to a degree, the linkage is capable of being broken, since bronze tipping is also found in conjunction with the angular upright branching of the var. *bourbon*. This association would seem more commonly found in the East than in the West.

Writing of his visit to the Yemen, Pierre Sylvain states that in several groves green-tipped forms were found associated with bronze-tipped, the colour of the young flushes apparently the only difference between them. Shortly before World War I, the Germans imported seed known in the Kilimanjaro region of Tanganyika as the 'Menado coffee' from the East Indies, and the author saw many trees of this variety in 1925 shortly after the ex-enemy estates had been brought back into production. The trees appeared to have the angular upright form of branching of var. *bourbon*, but the colour of the young flushes varied from green to a light and also a very pronounced bronze colouring. Some of the 'Kent's' coffee seems to follow suit, though this may be on account of hybridization since the strain was evolved.

The var. *bourbon* coffee of the Western Hemisphere appears to have more vigour than that found in Africa or the East, so that in many countries it is favoured at the lower and warmer altitudes, whereas in Africa and the East it is often said to have less stamina than the bronze-tipped coffees when it is grown in the marginal and warmer areas.

Perhaps the difference is brought about by chance, and because there is more moisture where the extra vigour has been seen, since Arabian coffee will grow more happily even at warm temperatures if it does not lack water.

There is one query which needs answering. Several authorities have studied the root systems of coffee in different soils and environments and have found varying percentages of surface roots and moisture-seeking roots at depth. If the different forms of coffee vary in their branching habits above ground, it is natural to suppose that they may vary in the branching habits of

their roots. Do the forms which exhibit angular branching tend to grow with a similar habit below ground? If so, their rooting systems may be deeper and this would account for the vigour of var. *bourbon* at lower altitudes in regions where the soil is friable.

In India and Indonesia we have industries which started early in the history of coffee cultivation, and many of the trials and experiments which built up our knowledge of how to cultivate Arabian coffee on a plantation scale, were carried out in these two countries. At first planters in East Africa leaned largely on the knowledge gained in India and the former Dutch Colonies, especially with regard to nursery techniques, planting distances, pruning, and the use of shade and cover crops.

With this last practice they went astray, for there is not enough moisture in the soil in many localities of East Africa to bear coffee and cover crops together; hence mulching has become widespread instead. In India and Indonesia the rainfalls are often heavier in the coffee districts, and in these regions cover crops would not necessarily be in competition for the moisture supply; indeed there might be too much moisture at times which the cover crops would help to use up, when mulching might sour the soil. A spacing of 6×6 ft. is still largely practised in India, but here again the heavier rainfalls and the single-stem pruning system might permit of a close spacing which would not be wise in a drier area.

Methods must alter slightly in accordance with environment despite the findings of research in any one place, hence what is good in East Africa may not be the best elsewhere, and vice versa.

The disastrous effect of the appearance of the leaf disease in Ceylon, the East Indies and India, panicked the authorities and the planters into the abandonment of Arabian coffee planting in all but high-altitude favoured localities where the disease did not appear so virulent. Little was known then of how to cope with such a disease, how to ameliorate conditions so that its presence could be borne in areas where the financial strength of the industries had been strained by other setbacks. In Ceylon planters turned to tea, whereas in the Dutch Colonies and later in India, other species of coffee were tried instead. Robusta planting developed at the expense of Arabian coffee.

In the East Indies the spreading form of robusta coffee was favoured. This in some respects resembles the var. *nganda* of Uganda, but is known locally as 'quillou' coffee. Seed was imported direct from the west coast of Africa, and so well known did it become that planting material was taken from Java and spread throughout the French Colonies.

Undoubtedly *Coffea canephora* and its various forms are more suited to the lower altitudes of Indonesia and India than is the Arabian species, yet, from the point of view of export values and future economy should the price of coffee fall, it is a pity that a coffee of lower value is being grown so extensively, when, with the knowledge we have today, Arabian coffee might succeed despite the presence of the leaf disease. Even in Ceylon Arabian coffee might prosper if it were cultivated and cared for in the modern way.

The discovery of 'Kent's' coffee in India was most opportune, and the use of this variety is becoming more widespread as its vigour and disease-resistance becomes known. Movements of varieties have been (*a*) from India to Java and back again to India, (*b*) the spread of the var. *arabica* to Holland via Paris to Martinique and thence to the Western Hemisphere and back via

Jamaica to the Edinburgh Botanic Gardens, thence to Nyasaland, Uganda and East Africa; (*c*) the travels of var. *bourbon* from Réunion Island to the French West Indies and the Western Hemisphere, and also via French missionaries to East Africa; lastly, the movements of 'Kent's' coffee from India to East Africa, and of 'quillou' robusta coffee from the west coast to Java and thence to many other parts of the world.

All these and many more forms and varieties which are not considered of such value, have originated from the mixed Arabian seed taken from the Yemen of South Arabia, and from robusta seed taken from the west coast of Africa. The most favoured varieties to-day, which are being taken more and more into cultivation in substitution for other kinds, are the bourbon and 'Kent's' varieties of Arabian coffee and the 'quillou' or 'nganda' forms of robusta coffee.

In India a great deal of selection and hybridizing is proceeding with Arabian coffees to keep the disease-resistant qualities of 'Kent's' coffee and yet improve yields, and also to select high-yielding varieties of better quality robusta coffees adapted to Indian environments. There is a large and increasing internal consumption in India for which the robusta kinds are of value.

India

History

It is difficult to ascertain the truth about the introduction of Arabian coffee into India. It is generally agreed that it was brought from Arabia by a Mohammedan pilgrim named Buba Budan in the seventeenth century, who took seven seeds with him on his return to India from Mecca.[30]

Royle in his *Productive Resources of India* mentions coffee of fine quality which was cultivated on the coast of Malabar and also extensively in Coimbatore. The earlier reports of the Journals and Proceedings of the Agricultural-Horticultural Society of India contain references to the cultivation of Arabian coffee in many places where it was obviously unsuited and later abandoned.

Coffee cultivation was afterwards concentrated in Madras, but the start of the European industry began when a Mr. Cannon planted coffee at Chikmuglur in Mysore and established a plantation there in 1830. It was cultivated also by a Mr. Cockburn on the Shevaroy Hills about the same time and a Mr. Glasson opened up a plantation at Manantoddy in 1840. Planting material was taken to the Nilghiri Hills in 1846.

Many were misled regarding the requirements of coffee in the early days, thinking that the Arabian species required a warm climate. Eventually opinions changed and Spons said, 'The most suitable climate for Arabian coffee is precisely that which Europeans prefer.' A number planted their coffee on land known as grass or bamboo land, where the estates failed and not a trace of them is to be seen today.

After the earlier attempts to grow coffee, attention was given to South Wynaad, with little success during the ensuing years. A number of the estates planted in 1855 and 1856 were opened up too hastily and subsequently failed.[30] There were about 9,900 acres under cultivation by 1862.

It does not seem to be generally appreciated that a native coffee industry

was the first to develop, and that this subsequently marched with European planting. In Madras in 1868 there were 29,900 acres of which rather more than 8,400 were native grown. In Coorg in 1882 there were 212 European planters and 4,594 plots belonging to native growers, the acreage being nearly equal because the average size of a European plantation was 195 acres and a native plantation only 8 acres. The average yield obtained by a native grower was said to be 3 cwt. per acre, while that of a European was 7 cwt. per acre. Most of the native coffee was prepared by the dry method and hulled with pestle and mortar.

ENVIRONMENT

The coffee-growing region now lies in the hills and on the plains inland from the Malabar Coast to the south-west in Southern India. The coffee is grown at varying altitudes but mainly at 3,500 to 4,000 feet.[9] Whereas the tendency is to grow Arabian coffee at the higher altitudes and robusta coffee at lower levels, the climate of the main coffee-growing region is such that both species are often grown successfully side by side. The Arabian coffee succeeds in a region where the temperatures might be considered too warm, possibly because of high rainfalls and a satisfactory supply of moisture in the soil.

An idea of the area is obtained from the list of regional coffee nurseries in operation during 1950 under the ægis of the Indian Coffee Board. There are two in Mysore, three in Coorg, two in Malabar, one in Cochin, two in Nilghiri, two in Coimbatore, one in Shevaroys and one in Vizagapatam: fourteen in all. Seedlings and planting material of both Arabian and robusta coffee are raised in these nurseries to meet the increasing demand for planting material of selected strains developed at the two research stations.[25]

There are in general four seasons affecting seasonal growth,[17] though there are separate wet and dry periods in two more distinctive seasons. Mayne gives the four seasons as follows:

(*a*) The dry season from the end of November to the middle of March, a period which covers the harvest and post-harvest rest period of the Arabian coffee. This is the cool season when growth is at a minimum. Differentiation of the flower buds takes place towards the end.

(*b*) The hot weather period from March to the end of May or early June. As the temperature rises, vegetative growth begins even though no rain may have fallen. About nine days after a shower of rain approximating a quarter of an inch or more, the coffee flowers, and there is usually a single blossoming period in late March or during April. If the rains are hesitant and poor, then there are smaller and successive blossomings usually resulting in a poor crop.

(*c*) South-west monsoon from early June to end of August. When the rains have begun, a rapid vegetative development takes place and the greater part of the annual shoot growth is initiated. During the rapid growth development, the swelling of the set fruit is slow. Towards the end of May when growth slackens, the development of the fruit is accelerated and continues to the end of August. Vegetative growth is therefore virtually at a standstill for a while and does not begin again until August and then continues through September to October. Rayner[21] believes that leaching, especially of soil nitrates, may be responsible for the slowing up of growth during the peak period of the rains.

(*d*) North-east monsoon from September until the end of November. In late September the first indication of axillary bud differentiation becomes visible on the preceding hot weather shoot growth.

The rainfall of the coffee districts is said to vary between 55 and 115 inches per annum[22] but in most cases it appears to be from 80 to 100 inches. The rainfall at the research station of Balehonnur in Mysore State over a ten-year period has averaged 104·23 inches, and at its sub-station in Coorg, 73·29 inches.

The good rains begin about early April and gradually develop throughout May. June, July and August are the heavy months with the fall tailing off in September and October and becoming short in November. The dry season is, therefore, from December to March, and this corresponds with maximum temperatures of from 80° to 93° F. and minimum temperatures of 51° to 55° F. In other words, the night and day temperatures are more widely divergent at this time.

At Balehonnur the average maximum temperatures fall and reach their lowest from late June to early September during the rains, i.e., about 72°–74° F., but the minimum temperatures rise and reach their highest for a while, round about 65° F. from May until October.

The temperatures are therefore more equable during the rains while flowering, fruit set, and vegetative growth take place; they are divergent and really too warm during the harvesting period when there is very little rain and when growth is at a standstill.

From these data one might assume that the temperatures are a little high for Arabian coffee for a comparatively long period of time, and a little low for robusta coffee during the dry season. These faults are ameliorated by the universal practice of shading coffee, and offset by a satisfactory moisture content of the soil.

The soil is of medium texture, often lateritic in nature and generally fertile. The slope of the land is not very steep but in general the country is hilly.

Meteorological data

The following figures are extracted from the Indian Research Reports.[25]

RAINFALL RECORD OF THE COFFEE RESEARCH STATION, BALEHONNUR (MYSORE)

Month	*Rainfall recorded in inches*										*Average for 10 years*
	1940	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*1948*	*1949*	
January ...	0·00	0·05	0·00	0·47	0·03	0·00	0·00	0·36	0·26	0·00	0·12
February ...	0·08	0·00	0·00	0·00	1·00	0·00	0·03	0·00	0·00	0·00	0·11
March ...	0·00	1·05	0·00	0·15	0·60	0·00	0·52	1·86	0·19	0·44	0·48
April ...	2·84	1·66	4·63	2·06	1·04	3·92	9·05	1·56	9·94	2·16	3·89
May ...	6·77	4·46	5·49	11·76	5·78	2·73	4·28	5·21	2·41	6·61	5·55
June ...	22·91	24·34	19·52	13·47	7·81	8·65	23·53	9·90	15·67	10·50	15·63
July ...	29·94	32·16	45·95	47·43	41·61	37·52	35·80	35·97	30·93	24·60	36·19
August ...	33·85	21·31	20·14	9·89	10·09	10·72	37·93	30·34	39·49	25·52	23·93
September ...	3·07	5·34	5·39	16·11	2·92	9·11	11·51	9·80	6·43	14·80	8·49
October ...	7·71	8·76	7·18	15·29	12·42	4·25	3·56	2·62	6·80	7·99	7·66
November ...	7·05	0·21	0·21	2·53	2·71	1·08	7·04	1·14	8·59	1·43	3·20
December ...	0·70	2·22	1·37	0·01	0·07	0·00	1·09	0·91	0·08	0·00	0·65
Total ...	114·92	101·56	109·88	119·17	86·08	77·98	134·34	99·67	120·79	94·05	105·90

RAINFALL RECORD OF COFFEE RESEARCH SUB-STATION, CHETHALLI (COORG)

Month	Rainfall recorded in inches										Average for 10 years
	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	
January ...	0·02	0·00	0·00	1·24	0·00	0·00	0·00	0·00	0·50	0·03	·18
February ...	0·00	0·00	0·00	0·16	1·05	0·00	0·00	0·72	0·40	0·00	·23
March ...	0·00	4·61	1·78	0·42	0·33	0·00	2·02	0·00	0·00	0·02	·92
April ...	6·55	3·70	3·02	2·16	0·87	7·38	8·32	1·53	4·75	3·78	4·21
May ...	4·90	5·10	8·55	11·78	1·40	2·29	1·35	4·69	3·80	11·02	5·49
June ...	22·02	19·24	14·77	9·10	7·02	10·35	13·59	7·31	10·53	6·85	12·08
July ...	23·50	16·06	26·93	31·45	36·00	30·84	10·71	23·35	12·43	15·35	22·66
August ...	18·20	12·91	12·29	4·69	4·93	7·64	24·91	18·85	21·51	8·83	13·48
September ...	2·96	6·36	3·91	8·91	1·83	3·50	8·25	8·64	3·59	5·87	5·38
October ...	7·10	4·22	5·84	11·50	6·04	4·63	3·93	9·98	3·64	8·85	6·57
November ...	8·39	1·42	0·42	6·55	4·00	2·09	6·16	0·13	5·22	0·10	3·45
December ...	0·67	1·88	1·01	0·00	0·51	0·00	2·31	1·05	0·09	0·00	·75
Total ...	94·31	75·50	78·52	87·96	63·98	68·72	81·55	76·25	66·46	60·70	75·40

FIGURES ARE AVERAGES FOR 3 YEARS 1948/49–1950/51

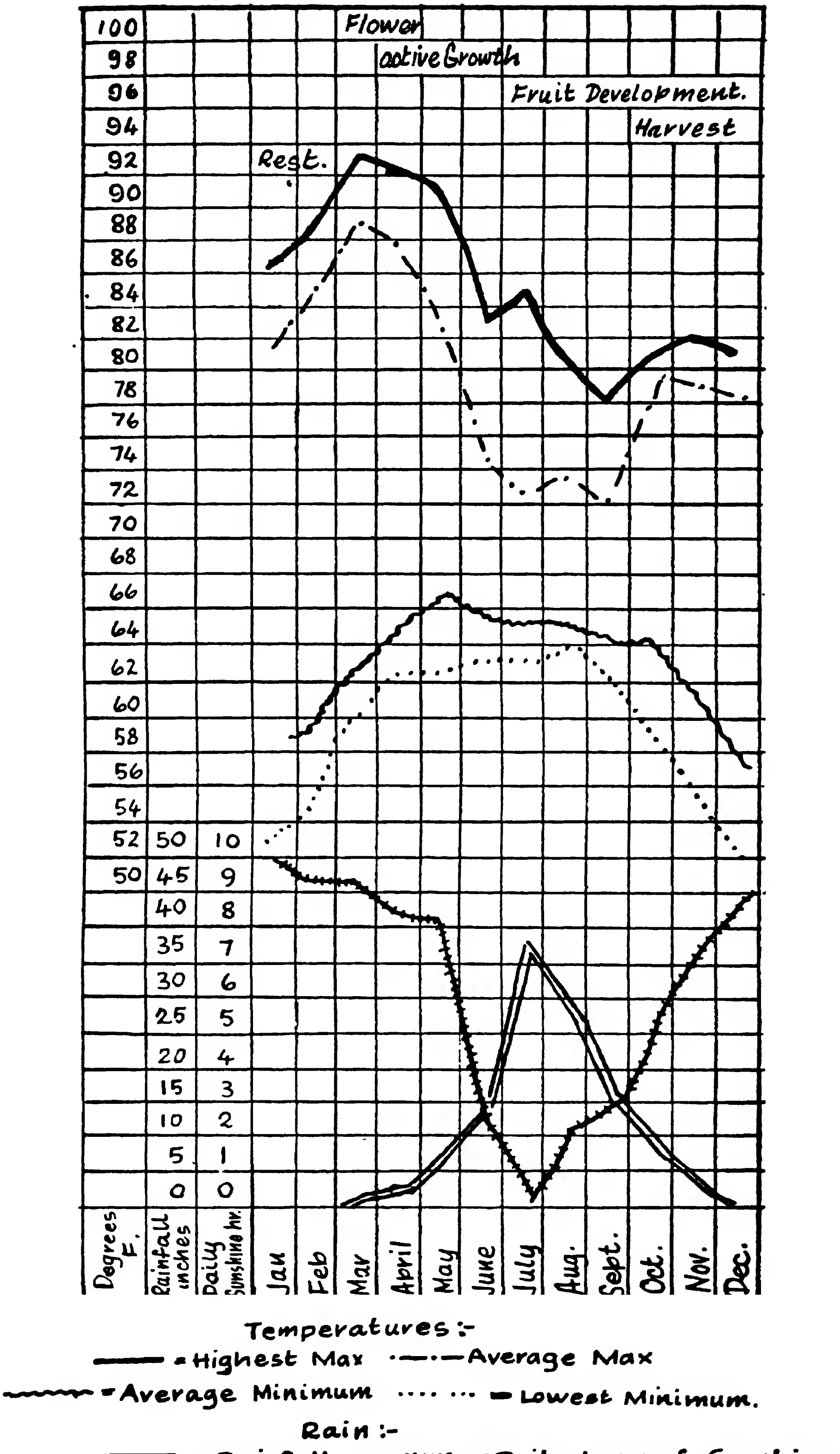
THE COFFEE RESEARCH STATION, BALEHONNUR (MYSORE)

Observation	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Mean*
Highest Max. Temp. degrees F.... ...	85·0	88·7	93·3	92·7	91·3	82·5	84·8	80·5	78·0	81·7	82·2	82·0	85·2
Lowest minimum Temp.	53·7	55·9	59·0	62·3	62·5	63·4	63·2	64·0	62·2	59·4	54·5	51·3	59·5
Average maximum ...	81·4	84·5	89·2	87·9	82·9	74·6	72·8	73·9	72·4	79·6	79·3	79·1	79·8
Average minimum ...	58·5	59·9	62·7	65·7	66·9	65·9	65·6	65·5	64·7	64·8	60·9	57·1	63·1
Average hours sunshine per day ...	9·9	9·1	9·4	8·0	8·0	2·4	0·8	2·1	3·1	6·2	8·0	9·1	—
Rainfall in inches ...	T.	0·2	0·3	2·0	6·7	13·3	37·7	28·4	14·1	7·1	3·8	T.	Totals 113·6
No. of rainy days in month	S.	S.	1	6	14	26	30	28	24	12	6	0	147

Notes: T.—Trace. S.—Seldom.

FIELD TREATMENT

At first a number of planters raised seedlings to a considerable size in the nursery, then cut them back and planted the stumps. As many as 40 per cent died after they were planted out.[9] More recently the planting of seedlings potted in basket-pots has been preferred, and tests were made to discover at what age it was best to place the germinated seedlings in the pots. The earlier the better was found to be true, in other words, as soon as a seed



Flower
active Growth
Fruit Development.
Harvest
Rest.
Degrees F.
Rainfall inches
Daily Sunshine hr.
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
50
45
40
35
30
25
20
15
10
5
0
10
9
8
7
6
5
4
3
2
1
0
Jan
Feb
Mar
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Temperatures :-
= Highest Max
= Average Max
= Average Minimum
= Lowest Minimum.
Rain :-
= Rainfall
= Daily hours of Sunshine.

FIG. 35.

germinated and straightened its stem, but before the parchment shell was shed and the seed leaves expanded.[25] It is probable that the transplanting of seedlings in nursery beds would be best done at this stage, and not delayed until the dicotyledons appear. Further tests showed that with ordinary careful planting, more young plants survived in the field if they were planted direct from the nursery beds as root-plants, rather than those grown as pot-plants.

For many years Arabian coffee has been planted at a 6 × 6 ft., 6 × 8 ft., or 7 × 7 ft. spacing, though many estates are now planting at 8 × 8 ft., while the robusta coffee is being grown at 10 × 10 ft. or even 12 × 12 ft. apart. Arabian coffee has been pruned to the single-stem method, but capped once at knee or waist high to hinder the vertical growth and thereby strengthen the lower branches. After the capping, only one vertical shoot has been allowed to grow to make the trees five feet tall. Most of the crop is borne on the vigorous laterals produced under this system.[17]

The robusta coffee has usually been allowed to grow unchecked until it has formed a large shrub as much as fifteen feet high, the branches spreading out until they overlap about eight feet above the ground.[9]

Recent research in India has proved, in connexion with Arabian coffee, that only a very light pruning gives the best yields; merely the cutting away of dead wood, unproductive growths and 'gormandizers'. Today there is a tendency to follow East Africa in the adoption of a multiple-stem growth for both species of coffee.

Deep cultivation is carried out only in young clearings, whereas in mature coffee, cultivation consists of a light surface forking throughout to bury any litter, and the renovation of pits and trenches.[22] The trench pits are dug 18 inches deep, 18 inches wide and about 30 feet long between the rows, often regardless of the contour. They are left open until they are filled with debris and weeds which may be scraped into them. Then they are covered in and new trenches are dug in alternate spaces. Owing to the porous nature of the soil there is no overflow causing erosion.[9] It is usual to cut a fresh set of trenches every year so that every space is trenched once in four years.

Weeding has been done by hand or by hand hoes, it being usual to hand-pull the bigger weeds during the wet season, leaving the soil dirty to check soil erosion. Weeds are killed back by the drought which invariably follows the end of the rains. No mulching has been attempted on any planned scale.

Many trials have been conducted in regard to manuring the soil. Significant results have been few and far between, and it is now considered that a leaf mulch provided by shade trees is sufficient to maintain soil fertility. Any increase in yield from the use of artificial fertilizers has not given a reward sufficient to make them pay.[25] The general idea has been to apply quick-acting nitrogenous manures immediately after the rains, and phosphates and potash in the months preceding blossoming.[22] A number of planters believe in using any organic manures that are available, and some go to considerable trouble in turning their coffee hulls and pulp waste into a compost for this purpose.

SHADE TREES

A number of shade trees are used. These are *Grevillea robusta*, *Erythrina lithosperma*, *Albizia lebbek*, *Ficus* spp., *Eugenia* sp., *Dalbergia latifolia*, *Artocarpus integrifolia*, *Terminalia* sp., in order of preference, and a number

of the indigenous forest trees. Temporary shade plants and cover crops have been used, and experimented with, but recent tests tend to show that they compete too seriously for the moisture in the soil during the drier months.

It is a common sight to see coffee grown under jungle shade, where some of the larger trees have been left standing while the area was felled for planting. Some of the coffee growing under such shade is of excellent appearance. *Grevillea robusta* is the tree most commonly planted, usually at 20 feet apart, and the trees are topped at 18 to 20 feet to encourage them to branch. The dadaps, *Erythrina lithosperma*, are topped every year in September or October (towards the end of the rains), the branches being placed between the rows of coffee. Curtler says that some of the old dadaps forty to fifty years old were still healthy although they had been topped every year.[2] The object is to create a complete shade but not so dense as to cut out most of the light.

HARVESTING

Arabian coffee is all picked when it is ripe in November and December. Picking may start in October and continue into January in some cases. The yield per acre varies between 4½ and 5 cwt. per annum and the coffee is prepared by the wet method. On account of the low minimum temperatures the fermentation process is often prolonged beyond three days at the higher altitudes, so that extra tankage space must be available for the daily pulping.[9]

COFFEE VARIETIES

The original Arabian coffee appears to have been a mixture, of which a large percentage was of the bronze-tipped var. *arabica*. There have been movements of coffee and importations of seed from other regions during the years, but a revolution can be said to have taken place in 1911 when the variety now known as 'Kent's' coffee was discovered on Mr. Kent's estate at Doddengoodda, a few miles from Aldur in the State of Mysore. The first seed was taken from a very healthy and heavy-yielding tree and Mr. Kent propagated this rapidly from seed, taking care to bag the trees at blossom time to prevent cross-pollination.

'Kent's' coffee proved resistant to diseases and pests, in particular to the leaf disease, and much of the older coffee has been discarded in favour of the new strain.[31] Robusta coffee seed was imported from Java when the leaf disease became prevalent in Asia.

RESEARCH

Research was begun during the British régime at the experiment station of the Mysore Department of Agriculture at Balehonnur, and the coffee experiment station of the United Planters' Association of South India at Sidapur in Coorg. The Research Department of the Indian Coffee Board is said to have come into being when the former Indian Coffee Market Expansion Board started to finance the 'Coffee Quality Scheme' which was started in 1939 under the aegis of the Imperial Council of Agricultural Research. The activities of this organization gradually expanded and culminated in the transfer to the Board of the Balehonnur and Sidapur experiment stations. Meanwhile the Woddermotte estate at Chethalli,

Coorg, was bought in 1947 for the opening of a sub-station representative of this important coffee region, because there was more room for expansion than at Sidapur. Work at Sidapur was thenceforward abandoned.[25]

Most of the experimental work at Balehonnur and Chethalli has received full comment in earlier chapters of this book. A great deal has been done to hybridize forms and varieties of both Arabian and robusta coffees with a view to obtaining high-yielding disease-resisting trees. Among other varieties the cv. 'maragogipe' has been used in crossing with 'Kent's' coffee, and the work has already led to the production of better strains which are now being supplied to the government-controlled nurseries to raise plants for issue to growers.

Some of the more recent experiments laid down have followed those in East Africa and concern single- versus multiple-stem pruning, also methods of cultivation and mulching. Exploratory trials have been conducted to discover the best method of preparing robusta coffee by the wet process, and the following findings were published in 1951.[25]

(*a*) Pulping of fresh cherry was better than pre-soaking.
(*b*) Pulp-skins should be separated from the freshly pulped parchment.
(*c*) The reddish-coloured fluid should be drained away and the pulped parchment washed before the ferment.
(*d*) The fermenting parchment should be washed once after 12 hours, then drained and the ferment continued. The addition of 6 oz. of clean wood ashes per bushel of wet parchment is said to facilitate the completion of the ferment and loosen the mucilage.
(*e*) The parchment is washed (at Balehonnur) 36 hours after pulping.

DISEASES AND PESTS

The *Hemileia* leaf disease caused a severe setback to coffee planting in the early days before regular sprayings with Bordeaux mixture and improvements in cultivation made it possible to continue the economic production of Arabian coffee. Root diseases are considered the next important, if not the most serious menace today, since they lower yields by causing gaps in the older plantations of coffee.

For the same reason the various stem borers are a serious pest. Green scale is sometimes troublesome and the coffee berry borer is common at the lower elevations. 'Case-worms' have defoliated *Albizia* shade trees and have proved themselves an awkward pest to control.

BURMA

About the time when European coffee planting in India had progressed and proved successful, attempts were made to introduce planting material into Burma. The Arabian species was found to grow best in the Toungoo Hills whereas Liberian coffee did best in the region of Tavoy. A flourishing coffee industry did not, however, develop in Burma, and any coffee grown there today is used for local consumption.

MALAYA

GENERAL

According to an official leaflet published in 1940,[1] the cultivation of coffee began in Malaya with the introduction of Liberian seed in 1875, though it is said that Arabian coffee was tried in Malacca as early as the eighteenth century but did not prove a success.

During the years 1880 to 1898 Liberian coffee was grown on a considerable scale. A large amount of British capital was invested in the Klang district, and estates were opened up in the districts of Selangor, Negri Sembilan and Pahang. By 1930 only 10,000 acres were being cultivated.

The chief reasons for a loss of interest were a fall in market prices consequent on increased production in Brazil, the investment in rubber production, and insect pests. It is also evident that a number of mistakes were made in the methods of cultivation. Even today, it seems, the growers have a good deal to learn especially in the choice of the best environment and soils.

Other species and strains of coffee have since been imported and tried from time to time. Unfortunately the nomenclature is poor, since forms are given specific names in a very loose manner, doubtless inherited from Java. *Coffea excelsa* is said to be a 'Liberian type' by several authors,[1 6 14 16 20] as also is the so-called *C. abeokutae*, and *C. dybowski*. *Coffea robusta*, *C. quillou*, and *C. ugandae* are all given as separate species of 'robusta type', whereas they are all forms of *C. canephora*. The fact that the excelsa coffee is linked with *C. liberica* is interesting, for this upholds the author's view that the so-called excelsa coffee grown must be a small-seeded Liberian coffee or a hybrid of some kind or other, and not the tree-like *C. excelsa*, first described by Chevalier.

Of course, as is stated in the chapter on the botany of coffee, clarification of the taxonomy regarding the excelsa species must await further study. In the other species of coffee we have a divergence in form, i.e., an upright style of growth undoubtedly becoming tree-like in the natural state, spreading, or shrubby growths and even dwarf forms. It is natural to suppose, therefore, that the excelsa species will have shrubby and dwarf forms as well, accounting for the doubts of Chevalier, and the over-generous listing of specific names within an excelsa grouping. The author prefers to consider the type species as a tree originating in semi-arid country, and keep an open mind regarding the shrubby, small-fruited forms, which may on the one hand be akin to the Liberian coffee, but which may be forms of *C. excelsa*—certainly not species within an excelsa grouping. In course of time one or two forms may be found to be sufficiently distinct to give them varietal names, or call them cultivars.

Be this as it may, it is obvious that there are four coffees grown in Malaya today, and in order of importance they are (*a*) Liberian; (*b*) a form of excelsa or a small-seeded Liberian; (*c*) robusta, i.e., *Coffea canephora*; and (*d*) Arabian coffee.

The coffee exported is of a mixed kind and of inferior quality. A great deal is consumed locally where there is a considerable demand.[14]

Most of the Liberian coffee of recent years has been grown by Asiatics who have a taste for this coffee, while several small estates have favoured the robusta kind. One or two of the big rubber-planting industries renewed their

interest in these two species of coffee because the internal market is a steady one. The acreage under Liberian coffee and the coffee trade of Malaya are shown in the following tables:

COFFEE TRADE IN MALAYA IN 1930[20]

	Raw		*Tinned*	
	tons	*value*	*lb.*	*value*
Exports	6,010	\$910,400	56,618	\$162,593
Imports	2,217	\$2,612,890	636,480	\$134,416
Net Imports ...	3,793	\$1,702,490	579,862	\$28,177

OFFICIAL FIGURES (COMMUNICATED)

Year	*Selangor*	*Remainder of country*	*Total*
	acres	acres	acres
1947	5,428	3,530	8,958
1950	5,634	3,317	8,951
1952	6,185	3,114	9,299
1953	6,691	2,595	9,286

Robusta coffee can be grown in conjunction with rubber and become of value when rubber prices are low or when a field of rubber is rejuvenated. The Liberian coffee thrives on the alluvial muck clays of the coastal districts and is tolerant of shallow peat overlying clay when low-lying land unsuited to rubber is drained. On some estates the Liberian coffee has suffered floods in season without total loss.

Arabian coffee is not cultivated to the same extent. It is found on higher ground in the Cameron Highlands but has seldom grown healthily or yielded well, doubtless because it has been planted on granitic soils. Shade has seldom been used and the coffee has not been grown particularly well.

Planting distances have been 8 × 8 ft. for Arabian, 10 × 10 ft. for robusta, 10 × 12 ft. and 12 × 12 ft. for Liberian coffee and the spreading form of the so-called excelsa coffee. All the species have been pruned to the single-stem method, the Arabian being topped at 4 ft. 6 in. high, and the robusta and Liberian coffee at 5 ft. 6 in. Several authorities have pointed out that clean weeding in the drier months and leaving the softer weeds growing in the wet months is the best policy, because cover crops such as *Calopogonium*, *Tephrosia*, and *Crotalaria* definitely retard the coffee and depress yields. It is doubtful whether mulching would be economical.

HARVEST AND PREPARATION

It is said that at Serdang there are no distinct fruiting and resting seasons, though most of the crop is harvested in April and May, and November to January. Average yields per acre per annum of cherry coffee over the 1928–35 period at the Serdang Experiment Station would appear to have been 8½ cwt. robusta, 26 cwt. 'excelsa' and 16 cwt. Liberian coffee. When these figures are calculated as cured bean, the excelsa yields are the most economic in relation

to local prices for internal consumption. It appears that the trees were raised from seed imported from Java in 1925, so they would be nine to ten years old at the end of the testing period. The proportion of fresh cherry by weight to dry cured beans is given as Liberian 10 to 1; excelsa 7·5 to 1; robusta between 4·5 and 5 to 1.[14]

Coffee cherry is picked ripe and prepared by the wet method on the estates, and by the dry method among Asiatic and small landholders. In the latter case, portable palm-leaf thatch coverings are used to cover the drying cherry on the barbecues during rain and at night. When dried, the cherry is passed through dehusking machines which are made locally of hard wood. These are not very efficient, so the cherry has to be treated several times to remove all the husk. Pressure is exerted during the process, and since the beans may still have too great a percentage of moisture they are often flattened and distorted out of shape. Winnowing and hand-sieving completes the task, after which the coffee is bagged and sold to Chinese dealers.

PESTS AND DISEASES

The worst diseases are (1) the leaf spot disease *Hemileia vastatrix* which attacks Liberian and Arabian coffee but not robusta, especially where the plantations are neglected; (2) *Colletotrichum coffeanum* which causes brown blight, and several root rots. The worst pests are the green scale, the clear wing hawk moth caterpillar, and the berry-bean borer *Stephanoderes hampei*.

CLIMATIC CONDITIONS

It will be seen from the table of temperatures and rainfall that the temperatures are fairly steady throughout the year, with November, December and January the coolest months. Even then the maximum temperatures are too high over most of the country for Arabian coffee to do well. They should be ideal, however, for the Liberian and robusta species. In the Cameron Highlands the minimum temperatures are on the cold side, even for Arabian coffee, but this would not matter, perhaps, if there were some drier months with less rain. The rainfall itself is steady, with seldom less than four or five inches each month. It is this, and the dull weather which goes with the showers, that precludes the use of shade trees. (*See* Tables.)

INDONESIA
(formerly the Dutch East Indies).

GENERAL

One cannot help but feel great sympathy for the Dutch in the loss of their colonies in which they did so much for the benefit of the peoples and the islands as a whole. They carried out an immense amount of research on coffee, and had this not been brought to an end by the Japanese occupation during World War II, and the political troubles afterwards, then they would doubtless have equalled, if not surpassed, our present knowledge of coffee production and cultivation.

When the leaf disease hit the Arabian coffee so badly at the lower altitudes in Java, the Dutch did not give up coffee growing as we did in Ceylon. They

MALAYAN METEOROLOGICAL RETURNS

TEMPERATURES IN DEGREES FAHRENHEIT. AVERAGES FOR 11 STATIONS

	Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total rainfall*
Highest maximum ...	89·9	92·4	92·6	92·8	92·7	91·9	91·3	92·5	90·0	91·3	90·1	89·8	—
Lowest minimum ...	69·0	68·7	69·7	71·8	71·8	71·2	69·7	70·5	72·8	70·7	70·1	67·7	—
Average maximum ...	86·7	88·5	89·0	88·6	88·8	89·3	87·9	89·5	87·8	87·8	86·1	86·5	—
Average minimum ...	72·7	72·8	73·2	74·1	74·2	74·5	73·0	73·9	73·3	73·3	72·7	71·7	—
Rainfall in inches ...	9·74	5·78	8·11	7·62	7·19	5·42	6·34	5·05	8·49	9·61	12·21	8·95	95·51

CAMERON HIGHLANDS, TANA PATA, PAHANG—4,750 FT.

	Jan.	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total rainfall*
Highest maximum ...	76·0	76·0	78·0	77·0	78·8	77·0	76·0	77·0	76·4	76·9	75·4	75·0	—
Lowest minimum ...	46·0	45·0	46·0	52·0	45·0	51·0	50·0	50·0	50·8	51·4	54,2	44·2	—
Average maximum ...	72·1	72·7	74·3	74·5	74·3	74·5	72·8	73·3	72·8	72·6	71·7	71·2	—
Average minimum ...	56·2	55·5	56·8	58·1	53·0	56·5	55·3	56·1	55·2	58·0	58·3	53·0	—
Rainfall in inches ...	6·17	3·36	9·74	9·44	8·84	8·14	4·95	3·52	9·89	9·06	15·64	5·53	94·28

Warning.—These figures are made up from a number of returns and stations. Although approximate averages they are sufficient to give an idea of the climatic conditions and seasons.

carried on and imported all kinds of species, varieties, and forms of coffee from elsewhere, and quickly discovered that some of the robusta coffees were considerably immune. They then carried on a campaign to hybridize the different kinds and to graft one upon the other, to improve the yield and especially the quality of robusta and other coffees while retaining resistance to the leaf disease.

They cannot be blamed for the confusion in the botany and nomenclature of coffee, for this has always been world-wide, and none of the world's herbaria have sorted out their dried specimens into proper species, varieties and forms at the time of writing. The Dutch were forced to relinquish their research while we in East Africa and India carried on and found that grafting was not, on the whole, a paying or a satisfactory proposition except for top-working and possibly for the rejuvenation of trees on plantations that are exceptionally well managed.

At the same time the Dutch were also experimenting with grafting high quality coffee on nematode-resistant stocks, an aim which may yet prove imperative in regions where this pest is troublesome. They were also beginning to consider rootstocks of various kinds adaptable to different soils, upon which scions of high quality coffee could be grafted. They believed that grafting was the proper way to propagate useful hybrids which would not grow true from seed, whereas we have since developed propagation by cuttings and have found this to be a better method.

The planters and the government were great believers in shade for coffee and also in cover crops to shade the soil, to smother weeds and help prevent erosion. Their orderly, shaded, and well-managed plantations were object lessons to planters elsewhere long before World War II began, and their method of preparation by the wet method left little to be desired.

When research had progressed in East Africa our knowledge had been built up on what had been done before in the Dutch Colonies and India, and thenceforward it was as though the three were advancing hand in hand until the Dutch had to let go. Despite this, their coffee men continued to do much that was valuable under the most difficult conditions.

HISTORY

The first Arabian coffee seed introduced into Java in 1696 must have been planted in an unfortunate situation, for the seedlings are said to have been destroyed by floods. A further supply of seed was obtained from Malabar, India, in 1699, and by 1711 the first parcel of 894 lb. of coffee was shipped to Amsterdam.[13]

It took some while before enough seed and planting material were obtained to begin widespread planting. During the eighteenth and the first half of the nineteenth centuries the natives of Java had been persuaded by the government to grow Arabian coffee on a large scale, and it was not until 1870 that European capital was invested to any large extent. East Java then became the centre of the coffee-planting industry,[3] which grew to considerable proportions in the following decades. In 1902 the total Javan crop is said to have been 22,272 metric tons of which 21,888 metric tons were produced in East Java.[23]

The *Hemileia* leaf disease appeared in 1876, and though it is said to have spread quickly through the islands, it did not cause a sudden disaster. The

restriction of Arabian coffee cultivation to the higher altitudes became a gradual process, and there were several other causes which contributed to the abandonment of Arabian coffee at the lower elevations. The larvae of stem-borer beetles caused havoc in many a plantation, and doubtless the temperatures were too high and the climate unsatisfactory for the Arabian species.

No efficient means had been discovered to combat the leaf disease, or the borer beetles when both became prevalent, so that the industry declined and reached the stage where it was rapidly becoming uneconomic in all but the higher altitude locations. It is stated by Schweizer[23] that wherever the plantations were unaffected by both the disease and the borers, the coffee showed no signs of old age or declining yields.

A new trouble called the 'starbloom' occurred in East Java, and this was apparent on young healthy trees where the corolla leaves and stamens were abnormally small, green in colour and sterile. It was said to be inherited when it occurred in Liberian coffee, but to the author the accounts of it would seem to indicate that a virus disease might have been the cause.

Then in 1900, seed of robusta coffee (*Coffea canephora*) was obtained and a plantation of this species was made in 1901.[13] It was found to thrive in the environment occupied by the Arabian coffee from sea level up to about 2,000 feet, and was attacked less by leaf disease. The seedlings were found, however, to be very variable.

Between 1903 and 1907 the garden of economic plants at Buitenzorg served as an introduction garden where other species including Liberian coffee were tried. The Liberian coffee was planted extensively about this time, but it soon proved susceptible to the leaf disease and a number of plantations were devastated.[3]

No sooner had robusta coffee proved itself than very careful efforts were made to propagate and distribute the seed. The principle adhered to was to collect the seed from the best trees, and to take seed from only one parent tree to plant up each new garden. In such a manner, in the beginning, a rough testing of the progeny began as the robusta industry spread in place of the Arabian.

To cope with the demand and the necessity to revive a dying industry, mixed seed from the original seedling gardens was supplied to many growers, but, as soon as a mother tree had been passed as a good seed-parent, it was vegetatively propagated by grafting to produce purer seed of better quality. From the centres where the grafting was being carried out, grafts and scion material were marketed, despite the fact that planters were afraid to use grafting on a large scale before this method of raising plants for commercial use had been proved.[13]

When robusta coffee established itself in favour, Schweizer[23] records how Vogler and Ottolander pressed for the production of a hybrid coffee as near to the Arabian coffee as possible in quality, but resistant to the leaf disease, which could be grafted on stocks which were resistant to borer beetle attack.

It is said that after two or three generations of selective breeding, 100 per cent increase in yields was obtained.[10] Neither the planters nor the authorities were satisfied with the quality of the robusta coffee, however, so a period of intensive hybridization began, using seedlings of Liberian, excelsa, Arabian and robusta coffees as parent trees, with their unknown genetical make-up. Also used were the varieties and forms of Arabian and robusta coffees which

had become known and had been selected as strains, such as the shrubby 'quillou' form of *C. canephora*, wrongly named *C. quillouensis* and the upright form which was named *C. ugandae*.

An alarming number of hybrids were obtained, many of them proving almost sterile, with all sorts of complications regarding scion and stock incompatibilities. However, the Dutch persevered, and their technique of grafting became more skilful.

Meanwhile, the robusta industry grew apace until it was the most important species grown, covering most of the area in East Java below 3,000 feet. The Arabian coffee remained successful at the higher altitudes and was still grown by many a native planter in Sumatra, Bali and the Celebes.[5]

In most of the grafting programmes, Liberian stocks were used until incompatibilities had been sorted out and some of the robustas found suitable. Then, in 1928, the seed of the *Coffea congensis* var. *charlotii* (which is now becoming accepted as another form of *C. canephora*) was received from Madagascar. This had been introduced to Buitenzorg by Cramer in 1908 but it proved to be very variable in character, of a hybrid nature, and bore very poor crops.[8]

It became apparent that this Congo form of robusta coffee was very resistant to the leaf disease, so a new era of hybridizing began. Throughout both periods of intensive hybridization—although some promising hybrids were undoubtedly born and grafted to propagate planting material—there were no outstanding successes resulting from deliberate crossing. Two hybrids became of note, and both appeared to have arisen by natural crossing between plants which were growing adjacent to each other.

The first was the 'Kawisari' hybrid, a cross between *C. liberica* and *C. arabica*. It yielded well, and when propagated by grafting it was found that the colour of the seed on drying was not fixed, some being bluish in colour and others yellowish. Attempts to select seed from this hybrid were later abandoned, so the Kawisari hybrid, which at first had seemed so promising, went out of favour.

Then a chance varietal hybrid was discovered, this time between the Congo robusta (*C. congensis*) and the quillou shrubby form of *C. canephora*. This proved a strong grower, almost entirely immune from leaf disease and a high yielder of good quality robusta type coffee. This was called the 'Congusta' variety by Cramer, and, to his irritation and annoyance, the 'Conuga' variety by Ferwerda. Hence both are the same hybrid.

The Congusta variety of robusta thenceforward grew in favour and was extensively propagated by grafting. From 1940 to 1942 this variety was being used on a grand scale to rejuvenate by top-grafting all the other coffee grown in the humid areas between 2,000 and 3,000 feet, a region which lies above the optimum environment for common forms of robusta coffee.[9]

SHADE

Most of the well-known shade trees have been tried and are planted among coffee in the Islands. *Derris microphylla* is said to be a favourite shade, but species of *Erythrina*, and the lamtoro, i.e., *Leucaena glauca*, appear to have been used extensively. In general the shade is light, with the *Leucaena* trees planted in rows wide apart. Whereas in other countries the lamtoro makes a very poor growth, in Java, Sumatra and Ceylon it succeeds in making a

sizeable tree after an early lanky growth when the stems tend to lean over at awkward angles.

In the East Indies the lamtoro might well be called a general-purpose tree. It grows from seed sown at stake, hence it is often sown in lines along the lower edges of terrace ridges, and is then kept clipped to form a hedge. It seeds prolifically and on clean-weeded plantations the seedlings can become troublesome. The Dutch often sowed lines of it between the coffee and then sickled the plants short to form a cover crop.

The authorities were always conscious of the danger of soil erosion, the effect of soil temperatures and the necessity for soil preservation, hence cover cropping was practised widely, without realizing, perhaps, that these inter-sown crops might compete for the moisture supply in the soil.

MANURING

Manuring was practised for many years, merely because it was thought to be the right thing to do. Planters varied in their beliefs and in the manures and quantities used. Following research, the matter was summed up by Shoep.[24]

He states that the intensive manuring of old coffee is almost certainly uneconomic. The intensive manuring of young coffee, he says, leads to rapid growth and early cropping, but if it is discontinued the succeeding crops will show a decline, albeit, if it is continued it will probably prove uneconomic in the end. At the same time, he advises that all organic refuse should always be returned to the land. This sounds rather old-fashioned, but it indicates that the Dutch had rarely found significant results when manures were used at an economic but insufficient rate.

CULTIVATION

The planning, lay-out, planting methods and estate maintenance used in the East Indies before World War II could be compared with those in Kenya at that time, though the rainfall is greater and hence the Arabian coffee at the higher altitudes in the East Indies matures with less die-back and without the troubles brought about by a moisture shortage in the soil.

PRUNING

It is common to see plantation coffee topped much shorter than elsewhere, with the object of throwing vigour into the lower branches. At its ultimate height a tree is generally topped at about five feet, and whether it has a single or several main stems, it has been grown and treated as though it were a single-stemmed tree. Multiple-stem pruning was to be seen in the later years before the war, but for the most part single-stem pruning was favoured.

From early practice in the East Indies and India, planters of East Africa took the ultra-correct system of pruning, and this was adopted until a more natural branching habit was found best. Each branch had to have its share of air and light, the knife being used to thin out the secondaries and tertiaries on a herringbone principle by rule of thumb.

THE PREPARATION AND PRODUCTION OF COFFEE

All the coffee is picked when it is red-ripe. Since Arabian coffee was abandoned in the lowlands, rather more robusta has been prepared by the dry method. Much of the coffee, and indeed, all the Arabian coffee is prepared by the wet method, i.e., the coffee is pulped, fermented, washed in washing channels and dried on properly constructed barbecues.

Before 1939, the Dutch East Indies were the third-largest producers of coffee. Production then reached 116,212 long tons, and normal exports were between 1 and 1·5 million bags per annum. In 1946 the exports were only 26,000 bags.[28] Of recent years the trade has moved from Batavia to Sourabaya. Macassar is the market for coffee grown in the Celebes, while Medan, Padang, Palembang and Sibolga are the chief markets of Sumatra. Semerang and Bandoeng are important Javan centres.

Some of the finest East Indian coffees of the Arabian kind were produced in the districts of Mandheling and Ankola in Sumatra. The Menado and Bungi coffees from the Celebes were renowned, as also was the Timor coffee. The principal Javan coffee districts were Buitenzorg, Preanger, Cheribon, Kadoe, Semerang and Malang.

Metcalf[19] gives information about the more recent coffee production in Indonesia. The following table gives the official figures of production for the years 1948–50.

Year	*Estate planted area in acres*	*Production in metric tons*			*Exports in metric tons*
		Estate	*Smallholder*	*Total*	
Average 1935–39	134,197	51,030	66,630	117,660	81,420
1948	71,660	8,200	15,800	24,000	2,220
1949	77,840	11,100	20,100	31,200	5,340
1950	94,000	18,500	40,000	58,500	13,560

By 1950, operations had been resumed on 122 estates with a total area of 94,000 acres. He says that about 6,000 to 7,000 tons were reported to have been stolen from the estates and marketed as native coffee. Moreover, it is estimated that 20 per cent of the annual production is not shown in the official figures for it has been smuggled out of the country, mainly to Singapore in exchange for Malay dollars, since there has been a high black market rate when these have been exchanged for 'rupiahs'. The current domestic consumption is said to be between 35,000 and 40,000 metric tons.

CEYLON

HISTORY

As stated in the opening chapter, certain accounts claim that coffee was introduced into Ceylon by the Arabs before the Portuguese reached the island, but doubts have been cast on the truth of such statements. Confusion may have arisen because some wild species of coffee are indigenous to Ceylon, and flowering and fruiting branches may have been taken from these by the

Sinhalese to decorate their shrines. The Dutch are said to have introduced Arabian coffee into Ceylon about 1690 and grew it chiefly in the lower-altitude coastal regions. On the cession of their territory, its cultivation was either carried on by the Sinhalese or the coffee was permitted to run wild.[30]

Impetus was given to a new industry by the establishment of an upland plantation by Sir Edward Barnes in 1825. Interest grew apace and by the year 1877 the estimated capital invested in coffee plantations amounted to £14,000,000. Exports are given as follows:[18]

Year	*Export in lb.*
1827	1,792,448
1837	6,756,848
1847	19,475,904
1857	67,453,680
1867	105,682,304
1877	109,627,280

It must be remembered that there was very little knowledge in those days concerning the correct environment for coffee and the best methods of cultivation, nor were there sound methods to control pests and diseases. Doubtless many a plantation was established at too low an elevation where temperatures were too high. In the rush to get large acreages planted, scant care would have been given to the selection of seed, to careful planting, or to shading, erosion-prevention and proper maintenance. One can visualize the overbearing and die-back which took place, the following years of recuperation, the appearance of green scale and borer beetles all leading to disappointment, low average yields and financial stringency. Speculation was rife by all accounts, and in 1847, twenty years before the leaf disease appeared in such disastrous proportions, a crisis arose during which estates were being sold at a discount.

The financial crash brought a measure of retrenchment and sanity. The best coffee fields were cultivated on better lines but many hundreds of acres of planted coffee were abandoned and grew wild. What better predisposing conditions could one have for the appearance and havoc caused by the leaf disease which attacked the estates in 1868–69? The leaf disease, green scale, root disease, borer beetles and leaf-eating caterpillars took their toll in the absence of sound methods of control. The yield which had already dropped from an average of about 7 to 4½ cwt. per acre, fell to no more than 2¼ cwt. per acre by 1876, so that the crop yield was no longer profitable.

The plantation owners turned to planting Chincona, tea and rubber instead, and since a loss of between twelve and fifteen million pounds capital had been involved, the whole world heard the resulting outcry and blamed the leaf disease as the chief cause.

COFFEE IN CEYLON TODAY

It is only natural that European interests, having suffered this setback, should turn to tea and rubber planting rather than try other species such as robusta coffee, which grew well elsewhere, as, for instance, in Java. The government did introduce Liberian, excelsa, and several forms of robusta coffee and grew these in the Peradeniya Botanic Gardens.

A number of smallholders had begun to grow robusta coffee successfully,

and by the nineteen-twenties were supplying the domestic consumers of coffee. Holland,[11 12] who did much to try and encourage its cultivation, gave some very good advice. He recounts, in 1922, how robusta coffee was being successfully grown on a variety of soils from sea level up to an altitude of 3,000 feet, in localities with a rainfall of from 80–150 inches per annum. He says that the demand for seed at that time had not allowed much scope for seed selection at Peradeniya.

The coffee was being grown under a light shade of the dadap, *Erythrina lithosperma*, the lamtoro *Leucaena glauca*, and *Gliricidia* sp. Single-stem pruning was adopted in the beginning with the trees topped at 4ft. 6 in. A spacing of 10 × 10 ft. was followed and mulching was continually advised.

Today, robusta coffee is the chief species grown. It is harvested during the period October to January and largely prepared by the dry method. Lessons have been learnt from the progress of events in other countries and methods of cultivation have been brought into line with modern practice.

Answering a questionnaire printed in the *Empire Producer* (now the *Commonwealth Producer*) in October 1935, the following facts were elicited regarding the consumption and imports. The consumption of coffee in Ceylon was then roughly ½ lb. per head, a total of 2,865,004 lb. The annual import of coffee was given as 2,856,785 lb. in 1934. It will be seen that this left a balance of 8,219 lb. to be made up by growers in the country, so there must still be plenty of scope for a local industry to provide for domestic consumption.

Ceylon coffee imports 1934

United Kingdom ...	2,371 lb.
India	16,864 „
Straits Settlements ...	65,457 „
Arabia	72 „
Central America ...	3,978 „
Java	2,768,043 „
	2,856,785 „

THE CLIMATE OF CEYLON

A table is supplied indicating rainfalls. There is a variation in the amount and in the period of rainfall in accordance with the situation and aspect of land, and as to whether a slope faces the South-West Monsoon or the North-East Monsoon. The mean annual temperature for all these meteorological recording stations is well above 70° F. except for the last two. The mean for Diyatalawa is 68·2° F. and that for Nuwara Eliya 59·2° F.[26]

The South-West Monsoon becomes definite in May and increases in intensity by the end of May or the middle of June. It continues but diminishes throughout August and sometimes into September. The North-East Monsoon begins after a transition period during October, and persists throughout November, December, and January, giving way to the South-West Monsoon again in April.

Nuwara Eliya is situated on the summit of the hills, Ratnapura is on a south-western slope, Colombo and Galle are to the south-west near sea level, Kandy and Kurunegala are a little too far to the north to be listed as situated on the south-western slopes of the main Hill Country.

RAINFALL AT STATIONS IN CEYLON

IN INCHES

Station	Annual average
Colombo	85·25
Jaffna	49·01
Trincomalee ...	62·96
Batticaloa	63·69
Hambantota... ...	38·53
Galle	92·37
Ratnapura	151·02
Kurunegala	82·05
Kandy	83·90
Badulla	72·72
Diyatalawa	62·81
Nuwara Eliya ...	93·35

INDO-CHINA

Most of the coffee is grown in Annam and Tonkin. The estates of Annam are situated for the most part on fertile red soils at altitudes of about 2,000 feet, in the Hauts-Plateaux, Mois and Darlac regions. Both Arabian and robusta coffee are grown at a spacing of rather more than 9 × 9 ft. apart. Stump planting is practised and methods of cultivation, despite considerable efforts to improve them, are still elementary. In Tonkin about 7,400 acres of coffee are grown by Europeans who often grow Arabian and excelsa coffee in mixed plantings. Although some shade their Arabian coffee, the excelsa species is grown without shade. The crop is prepared by both the wet and dry methods.

A limited amount of robusta coffee is grown in Cochin China and Cambodia. Despite the good quality of Arabian coffee in Indo-China, the trees are grown with difficulty on account of borer beetles which attack 25 per cent of the trees. The total production in 1937 was 1,500 tons of all kinds, of which 500 tons were consumed locally.[15]

THE PHILIPPINE ISLANDS

HISTORY

A Franciscan friar introduced coffee into the Philippines from Mexico, and reared plants in the Laguna Province. Most of these seedlings were taken to a town in the Province of Batangas. They started the coffee industry, and considerable areas were developed in 1859 when coffee growing was made compulsory by the Reyes brothers named Galileo and Santiago. On account of this, coffee was among the more important export crops during the years 1854 to 1894 until leaf disease affected the plantations so badly that many abandoned its culture.[4]

Despite the introduction of species resistant to the disease, the industry never recovered its previous importance so that domestic consumption became greater than the supply and coffee had to be imported from elsewhere. Production amounted to 4,373 tons of dried bean in 1948, but decreased to 3,913 tons in 1950, and this, coupled with a restricted import, pushed up

prices and gave encouragement to increased planting. The leading coffee-producing Provinces in 1950 were:

Batangas	...	1,300,000 kilo
Lanao	...	464,710 ,,
Bukidnon	...	433,820 ,,
Davao	...	346,600 ,,
Cavite	...	230,000 ,,
Cotabato	...	186,580 ,,
Mountain	...	120,800 ,,
Quezon	...	100,000 ,,
Zamboanga	...	74,400 ,,
Laguna	...	68,310 ,,

CULTIVATION

Arabian coffee does not thrive in the Philippines below 2,500 ft., robusta coffee is best grown from about 650 ft., up to 2,000 ft., where the rainfall is evenly distributed, and Liberian coffee thrives best from sea level up to the 1,000 ft. level. Excelsa coffee is classified by the Philippine authorities under a Liberian grouping, and it is preferred to all the other species by the islanders and is used for large-scale planting from sea level to the highlands. It is said to be drought-resistant, pest- and disease-resistant, and the soft pulp of the fruit permits the cherry to be pulped with comparative ease.

The usual planting distances are 8 ft. to 9 ft. 6 in. apart for Arabian coffee, 9 ft. 6 in. to 13 ft. apart for robusta coffee, and 14 ft. to 18 ft. apart for Liberian and excelsa coffee. The weeds are chopped or sickled two or three times each year, and whereas rich soils are not manured the authorities advise an application of nitrogen at the rate of about 1½ lb. per tree two months after planting on poor soils, with the same quantity of sulphate of potash applied just before the coffee flowers. The multiple-stem system of pruning is advised and pruning takes place soon after harvest.

Bananas are used for temporary shade and *Leucaena glauca* for permanent shade. Both are planted a year ahead of the coffee, the *Leucaena* being sown in lines midway between the lining out stakes for the coffee. As the seedlings of the *Leucaena* grow taller they are thinned to give temporary shade to the young coffee. They are thinned again as time progresses until the ultimate plants are at the desired spacing of about 30 ft. × 35 ft. The coffee plants are now planted with bare roots and with all the leaves according to the results of experiments carried out at the Inter-American Institute of Agricultural Science at Turrialba, which confirm similar experiments at the Lyamungu Research Station in Tanganyika.

Arabian coffee is harvested in the Philippines from December to March, robusta from December to April and the other two species from January to April. Both the wet and dry methods of preparation are used.

QUEENSLAND

There are doubtless several regions in Queensland where the various species of coffee might succeed. Indeed, Arabian coffee has been grown in small groves in cleared valleys to the extent of between 20 and 50 acres since the

early twentieth century. It has been grown at sea-level up to 1,500 and 2,000 feet and reported to yield at the rate of 15 cwt. per acre and bear its first crop in 2½ years. The high yield indicates the care with which the plantings have been cultivated, though the early bearing is indicative that the temperatures are too warm during the growing season.

It would indeed be of assistance if Australia could make herself self-supporting in cured coffee, for she imports a considerable quantity. Unfortunately it is not possible to mechanize most of the tasks on a mature plantation. Instead, a quantity of cheap labour—not to be found in the country—is required. Until the problem of labour is overcome, Queensland is unlikely to increase the cultivation of coffee.

South Pacific

There are several small islands such as New Caledonia where small quantities of coffee are grown. If attempts are made to grow coffee in small islands at low altitudes, wind breaks are desirable. The coffee should be kept topped at a low level or grown in the shape of a close-growing shrub. Liberian or robusta are the two species likely to succeed provided the soil is fertile and slightly acid, and the rainfall sufficient and well distributed.

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Chapter XVII

COFFEE PRODUCTION IN THE WESTERN HEMISPHERE

General

Anyone who studies the literature pertaining to coffee in South and Central America must gain the impression that coffee as a whole is treated more as bullion than as a crop needing specialized treatment. This is understandable, since most of the countries depend for their solvency and well-being on price levels and quantities. Today coffee provides approximately 75 per cent of the total value of the exports from the separate countries.

The men who rule the industries are not those who grow the product but those who handle it, cure it and sell it on the world's markets. They talk of thousands, even millions of bags, and estimate the number of trees planted in astronomical numbers. There is more information about valorization schemes, exchange rates, markets and grades than about how and where the coffee is grown.

In countries of smaller production, where every grower is literate and reached by easy means of communication, governments have distributed questionnaires in regard to acreages but have found that the resulting figures have never been dependable. The growers frequently open up portions of their land without bothering to measure the area, and they may have only a hazy idea of how many acres of planted coffee they own. Hence the acreage entered on such questionnaires is often a mere guess.

How, then, can one estimate, with any degree of accuracy, the numbers of trees planted, when half the growers are peasants who cultivate their coffee in gardens reached by mule transport, in mountain ranges remote from any form of agricultural inspection or teaching? Estimates of the number of trees planted in any one of these countries must therefore be fanciful. One reads, for instance, of 949,000,000 trees estimated for Colombia in 1946, 142,000,000 trees for El Salvador in 1945, 132,000,000 trees for Mexico, 566,000,000 for Venezuela, and so on, and one wonders on what data such figures have been based. Even the acreage figures must be suspect.

A clear-cut division can be made between Brazil on the one hand, and the other South and Central American coffee-growing countries on the other, in three important matters. For this reason Brazil is treated at longer length in the following pages, whereas, to avoid repetition, the others are considered chiefly in this generalization. The bulk of Brazilian coffee is unwashed, prepared by the dry method and hence of poorer quality, including as it does the 'hard' coffee with the Rio flavour. The bulk of the coffee from all the other countries is washed and treated by the wet method, so it is mostly good quality mild coffee.

Most of the Brazilian coffee is sown at stake. The trees are seldom pruned and the fruit is stripped from the trees once during each fruiting season. The coffee in all the other countries is mostly raised in nurseries before the seedlings are planted in the field. The trees are later pruned according to several systems, and the fruit is gathered during a succession of pickings only when it is red-ripe.

The Brazilian coffee plantations are mostly unshaded, and a large part of the area lies in a temperate region subject to frosts, while plantations in the other countries are shaded except at very high altitudes and are not subject to frosts.

In all the Latin-American countries there appear to be large well-managed plantations, but for the most part the coffee is grown by a great number of small landholders and peasant growers. In the countries producing mild coffees, these holdings are situated within transport distance of the larger estates to which the ripe coffee is sold and where it is treated and often cured. The big factory owners are called 'Beneficios', and without them a great deal of the coffee could not be treated by the wet method because the smaller growers have no pulpers or means of preparing parchment from their cherry coffee. The few peasant growers who are located at a distance from a central Beneficio, prepare their coffee by the dry method. Though it is of a lower grade it is still 'soft' or 'mild coffee' when the fruit is picked ripe and carefully dried before it is hulled.

In all these countries the coffee is grown in a great many environments at different altitudes and on different soils. Whereas some are ideally situated for temperatures, rainfall and fertile soils, much of the coffee is grown where moisture is short. Here and there the dry seasons are prolonged and practically no rain at all falls for periods of several months.

Such conditions are reflected in the annual production yields and export figures. The trees prosper during the good years and build up their strength until they yield a bumper crop. This is followed by over-bearing, with resultant exhaustion and a recuperative period lasting a couple of years. In some of the Central American states it would appear that coffee planting has reached almost the saturation point. Either the land suitable for coffee within reach of communications has all been planted, or the population is such that the limit of strength and of available labour has been reached.

In these countries the peak period of production occurred a few years ago, and there are signs now that yields are falling off on account of the deterioration of the soil and of the trees. The possibilities of increased production depend on several factors which are not easy to overcome. Firstly there is the problem of how to teach and persuade the thousands of semi-literate peasant growers to adopt progressive and more modern methods of cultivation. Secondly, communications and transport facilities must be provided to reduce costs and open up new areas.

The difficulties during the last war, together with the recent years of high prices, and the fact that so many of these countries depend on coffee exports for their purchasing powers, have brought the growers into federations backed by their governments. For some while these ruling authorities have been publishing books to teach the growers improved methods, such as the *Manual Práctico del Cultivo del Cafeto en México* published by the *Comisión Nacional del Café*, Mexico. At the same time roads and transport facilities are being improved.

This being so, there may not be any spectacular increase in the production of coffee for some years in many of the Latin-American countries. What is more likely is a more gradual and sounder progress, while the price of coffee remains at an economic level.

Erosion prevention must also receive attention, because very few are conscious of the need for this at the present time. The coffee is often planted

longer and more tiresome method of selection among plants of which the genetical make-up is unknown.

Unfortunately the greater part of the Brazilian cured coffee, despite the fact that it is of the Arabian species, is known in the world's markets as 'Brazilian' or 'hard' coffee. Hence much of the crop falls into low-quality, low-priced coffee. Brazil is therefore the country chiefly hit when there are world surpluses, and only the best quality coffees find a ready sale at economic levels.

On the other hand, Brazil might find herself in some difficulty were she suddenly to raise the whole of her coffee up to good quality milder grades. Her 'hard' coffee is liked in many parts of the United States and finds a special market for supplying a low-priced commodity for blending with higher quality mild coffees in shorter supply. Thus blends can be cheapened and at the same time supply liquoring categories to which large sections of the Western Hemisphere have become accustomed.

If Brazilian coffees having those harsher liquoring qualities were all first-class, then there would indeed be a world shortage of low-priced coffees for blending purposes. There are interests which would be alarmed at a sudden cessation of shipments of such coffees, and thus there are influences opposing such a change. In addition, many of the internal consumers might not like to be forced to alter their taste.

Several writers[33] have mentioned the fatalistic attitude of many of the growers. When prices are high they feel there is no need for improvement, and when prices are low they feel that improvements are not worth while and too expensive to carry out.

The wonderful cities of Brazil are a kind of façade behind which the vast expanse of countryside is underdeveloped, needing more and better roads and communications. The cities, and the industrialization surrounding them, have tended to lure labour from the countryside to the higher wages offered, and since the planters have made money during the recent spell of high prices, the wages of employees in the rural areas have risen in sympathy. This does not augur well for the future should prices fall again.

Coffee planting in neighbouring Latin-American countries has increased rapidly during recent years, and all of them produce coffee of excellent mild quality. These coffees would have an easier sale than Brazilian coffee should prices break. Moreover, there is a tendency today among the American people to appreciate the milder coffees.

Brazil is, therefore, in something of a quandary. If all her produce became good quality mild coffee there might be a world surplus of such coffee. Should the production of all coffees become much greater than the demand and the quality not be improved, then disaster might follow and Brazil lose her position as the leading coffee producer. The lesser evil is obviously to improve, not only her methods of cultivation, but also her methods of preparation. Also, of course, to obtain a greater variety in her industries and exports.

This is what the government is trying to do, deterred and severely handicapped by the conservatism of the people in the countryside, and by the lack of so much else, such as proper communications and progressive education in the areas remote from the towns.

VARIETIES GROWN

Almost all the coffee is Arabian, and the variety preponderating is known as 'nacional', or *Coffea arabica* var. *typica* Cramer, which in fact should be named *C. arabica* var. *arabica.* For some decades, however, there has been a growing tendency to plant bourbon coffee instead, and this variety is now being used for preference in all new plantings.

It is mentioned elsewhere in this book how several well-known varieties evolved in Brazil as mutants, such as the 'maragogipe' and the 'amarella' or 'Botucatu' coffee. These are still being grown by some planters but only to a small extent. They are, however, being used in the breeding programme in efforts to evolve better strains and new cultivars.

THE COFFEE AREAS

It is said[30] that Arabian coffee can stand a temperature as low as 32° F. provided there is no wind, but a lower temperature, even for a short while, will destroy all green growth. At the other extreme the trees show symptoms of suffering when the temperature reaches 95° F. Brazil lies partly in the temperate zone, and the temperature range where most of the coffee is grown, is between 63° and 77° F. The ideal is said to be between 65° and 75°, as close to 68° F. as possible. The minimum temperature for safe and economic coffee growing is in reality about 55° F., and though the temperature goes below this, and as high at times as 86° F., such extremes are unwelcome and harmful.

Brazilian planters are often scared of frosts, especially in São Paulo, South Minas Geraes and Paraná. Severe damage from frost occurred in the years 1870, 1886, 1902, 1918, and 1940.[34]

In São Paulo the best altitude appears to be from 1,600 up to 2,600 feet, but in the states of Rio de Janeiro, Minas Geraes and Espirito Santo, lower altitudes are better.

The rainfall has an important bearing on the success of coffee in Brazil for it is generally regular and falls in one distinct season from September to March. The drier season lasts from April to August, when, on the average, there are only fourteen days of rain.[10]

Coffee is grown in Brazil in regions with only 40 inches of rainfall, though the average annual rainfall is about 59 inches, so that in favoured localities the rainfall is higher still. A rich retentive soil is a helpful factor, and the practice of clean weeding eliminates competition for the moisture supply, but, in the absence of shade, or ground cover, or mulching, or any physical means of preventing soil wash, the loss of top-soil by erosion can be imagined. It is not surprising that the life of the coffee tree is considered to be not much more than fifteen years, or that shifting cultivation has been practised from the start.

Freak droughts occur at times, and the one which occurred in the state of São Paulo during 1940–41 is said to have been the most calamitous in living memory.[34]

Coffee bears in its third year, and flowering occurs between August and December. The flowering period lasts for three to four days, and the time varies according to the rainfall and temperature. Sometimes heavy and prolonged rains begin unexpectedly and bring about a fall in temperature, and

unfavourable seasons are marked by an absence of rain just before and after the flowering period. Early rains may accelerate flowering and then the flowers suffer from the lower temperatures which prevail at that time.

The fruit ripens quickly in the warmer regions when the rainfall is sufficient, but ripening is slower to the west and south-west of São Paulo. The harvest begins in April when there should be very little rain at all, but sometimes the rains are prolonged and heavy and cause severe losses.

Much of the fruit then falls, and is either washed away with the soil or buried by soil wash and then germinates. This would not happen, of course, if the fruit was picked as it ripened.

According to information given in 1945, the area considered suitable for coffee growing in Brazil is very extensive. It is said to stretch from the state of Ceará in the north to that of Santa Catharina in the south.[30] It grows exceptionally well in the Baturité, Maranguape and Aratanha range of mountains, in the state of Ceará and also in the municipalities of Crato, Jardim, Pacatuba and Viçosa. The state of Parahyba do Norte, where coffee is said to grow best, includes the municipalities of Bananeiras, Araúna, Alagôa-Grande, Alagôa-Nova, Guarabira, Campina and Arcia. Large plantations are found in the state of Pernambuco, especially in the municipalities of Bonito, Gravatá, Tríumpho, Garahuns, Canhotinhoo, Guipupá and Bom Conselho. The state of Bahia also has extensive plantations.

The whole region may be divided into two large zones, in one of which the moisture-laden breezes come from the sea, and in the other they come from the land. The first zone lies in those parts drained by the Parahyba river and its tributaries; the second zone comprises the plateaux to the west and south-west of the state of São Paulo, and the south-eastern part of Minas Geraes, mostly protected from the sea breezes by the Sierra do Mar.

The extension of coffee cultivation in the south depends on the incidence of hoar-frost, and the boundary line varies according to the altitude and lie of the land and according to whether the land is sheltered or not. The best climate is a temperate one free from frost.

THE LAND AND THE SOIL

Most of the land is undulating and the coffee is often planted on steeply sloping land—land that should certainly be protected by anti-erosion ridging, storm drains and the like, though very little work of this kind has ever been attempted.

The soil that is sought for coffee planting is a red, fertile, loamy soil known as the 'terra roxa'. Throughout the history of coffee growing in Brazil, the richest forest land has been used. The forests have been destroyed, the land sown—not planted with coffee—and the crop grown with the minimum of care and attention until the soil has become impoverished and the trees exhausted during periods of not much more than fifteen years.

At fifteen to twenty years the trees have been considered to be at the end of their economic lifetime, and this belief, emanating from Brazil, has led many to believe that coffee trees generally become uneconomic at this age. In fact, it is at such an age that coffee trees should be bearing their best crops and have many years of healthy life before them. The fault lies entirely in the methods of cultivation practised in Brazil.

In the beginning slave labour was used to clear the land and cultivate the

crop, so when land became impoverished and the coffee no longer healthy, the plantations were abandoned in favour of new planting on freshly-cleared land. Even when slavery was abolished labour remained cheap until recent years, so the old practice continued until much of the land used in the early days for coffee planting now lies fallow, or is used for other purposes.[33]

This means that coffee planting has tended to move farther away from easy communications, and on to land and soils not quite so good as those which were first used. During the last decade efforts have been made to bring back some of the older land to a state of fertility so that coffee might be replanted, but success has been achieved only by using large quantities of organic manures which cannot be found in sufficient quantity to benefit more than small areas. The urge to regenerate the old abandoned land began after the supply of rich virgin soils—accessible to transport routes and shipping ports—became more and more limited.[33]

THE PLANTATIONS

The difficulty of supplying enough manure will be apparent when the size and working of many of the plantations are considered. In São Paulo almost half the coffee plantations are from 165 to 1,000 acres in size but rather more than half the estates are smaller than 35 acres. About two dozen estates have 3,250 acres or more, and the world's largest plantation in the São Paulo State is said to have had, at the height of its success, at least 15,000 acres of coffee. These figures are based on the number of trees planted at an average of twelve feet square planting.

There are three systems operating. Firstly, there is the owner-planter who pays his employees and manages his own plantation, secondly the owner who pays contractors to carry out the work, and thirdly the owner who leases his plantation and takes an agreed share of the profits.

METHODS OF CULTIVATION

Even today, the number of planters who are beginning to cultivate their coffee on modern lines are few and far between. By far the greater number still follow the practices first adopted, practices which seem very strange and primitive, if not extremely foolish to planters elsewhere who have benefited by research and their own more progressive ways.

There is no stump clearing after forest felling. Usually no anti-erosion work is carried out. Clean weeding is practised as far as is possible and no overhead shade is used. Whereas planting distances were $3{\cdot}5 \times 4{\cdot}5$ metres, they are now generally $3{\cdot}5 \times 3{\cdot}5$ metres, or in other words about 12 feet apart. Small holes are dug 16 to 20 inches deep and refilled with top soil. Afterwards a small handful of seeds are sown at stake at each spacing.

According to hazard, and the energy of the planter, the seedlings may be thinned to two or three at each spacing, although it is not unusual to find four, five, or even six trees growing up together at each spacing.

The spacing is wide because the trees are allowed full growth. There is the scantiest of pruning to stop the trees growing too high, to reduce suckers, and to hack away dead and dying branches following frost, drought, overbearing and exhaustion.

It is frequently said that no manuring or mulching is attempted in Brazil, and this undoubtedly applies to the older coffee areas such as those in Rio de Janeiro and Espirito Santo States. There is a limited use nowadays, in the newer plantings in the States of São Paulo, Paraná, and Minas Geraes. Farmyard manure is considered the best kind of manure, coffee hulls second-best and commercial fertilizers inferior to organic manures.[33]

There are a sprinkling of estates in the newer areas where coffee is being grown on more modern lines, but the methods used in general are as stated. The principal use of labour is for harvesting and hand weeding when once the land has been planted. Mechanized cultivation is not practised (and it is doubtful whether it would be advisable) because it is necessary to keep up the labour supply for harvest time, and the planters cannot imagine men being employed meanwhile on other tasks than weeding.

Many writers of recent years have pointed to the increased returns which might be possible were the coffee to be grown on modern lines. A light shade would go far to even up cropping, maintain the health of the trees, prevent erosion, and damage from frost or intense sunshine. The planters say that shade would prosper the coffee-bean borer, but this might be so only if they continued their primitive methods of harvest. Nursery-raised seedlings of good stock planted at a closer spacing, at one plant to each hole, would immediately give a much higher yield per acre if the trees were subsequently pruned to a definite system.

Moreover, mulching and erosion-prevention would keep the soil intact and maintain the vigour of the trees. All these are sweeping changes which most Brazilians are content to ignore. According to them it would involve too much labour in a country where labour is growing scarcer. There is no thought of reducing acreage and cultivating smaller areas of higher yield. When prices are low the Brazilian dreams about what he might do if only the returns allowed him to spend money; when prices are high he is satisfied with returns and puts off the evil day. It is then that he recuperates his financial strength in order to live a pleasant life. Why should he spend good money adopting new methods which would be strange both to him and to his labour?

HARVEST

Though an ever-increasing number are beginning to pick ripe coffee and prepare it by the wet method, the percentage of these is still very small and most planters still follow the old dry method.

Of the latter there are two kinds, those who process only ripe cherry and take more care in its preparation, in the way the Africans now prepare their robusta coffee in East Africa, and those who strip the crop from the trees at the stage when most of it is ripe. This means that much of the cherry on the tree is over-ripe and beginning to fall, some of it is red-ripe, and some is almost green and certainly under-ripe. The first of these two methods produces a softer and milder product such as Santos coffee, while the second produces inferior coffee, though both depend on how the cherry is treated afterwards.

The planters point to the great saving in labour when stripping is practised. Instead of having several cycles of picking when only ripe fruit is harvested, there is only one picking during the season. Pulping and fermenting are also

by-passed, so what does it matter if the product fetches less when expenditures have been so little?

Before harvest the ground is smoothed and cleared beneath and surrounding the trees. Many do not even trouble to pick into baskets but strip and throw the coffee on the ground, using step ladders to reach the higher branches if the trees are well grown. Some may pick part of the crop into baskets and the smaller planters may harvest their whole crop in this way, though on the larger estates the cherry is gathered mainly from the ground.

The cherry is sieved to rid it of soil. Stones, twigs, and leaves are picked out of the sieves and the cherry is then sacked for transport to the drying ground or to the nearest point where a flume exists to carry the cherry in running water. It is not always washed before it is laid out to dry.

At the barbecues the cherry in all stages of ripeness—including fruits, perhaps, which had fallen of their own accord to the ground beneath the trees days before the stripping took place—is heaped up thickly on adobe, brick or concrete surfaces to dry in the sun. Such vast amounts of cherry are gathered each day that it would need a huge expanse of flooring to take the crop in a thin and proper layer. Indeed, some of the barbecues are very large, but even so they are not large enough to avoid heaping the fermenting cherry far too thickly.

As a result the coffee turns rank. Mildews and organisms grow on the fermenting mass of cherry, flies are attracted to it, and the result when the cherry is dried and hulled is 'hard' Brazilian coffee with the harsh Rio flavour. No one could think of a worse method of harvesting and drying good Arabian coffee.

One might sum up by saying that Brazil has produced so much coffee with such an influence upon world markets that the economics of coffee and the prices obtained for the varying sorts have received more notice than the means by which the coffee has been produced. Only of very recent years, when Brazil's neighbours had advanced to a competitive position and produced better coffee, did the authorities in Brazil awaken to the primitive methods used, or begin to take action.

Even then, every excuse was put forward. There was some organism in the soil, in the air, in the fruit itself found nowhere else but in Brazil to account for the harsh flavour, until a proper investigation was made and the obvious fault accepted. Nowadays planters are urged to prepare their coffee by the wet method, though it is difficult to get the majority to agree because pulping machinery and fermenting tanks are not owned by the thousands of smaller growers, nor could they easily afford them.

INVESTIGATION INTO CAUSE OF 'HARD' COFFEE

In an account of efforts to improve Brazilian coffee, Bally[3] remarks that there are two problems. Firstly, the elimination of small stones, wood debris and so on, brought about by the stripping of coffee cherry, during which it is permitted to fall on the ground whence it is gathered up afterwards, and secondly of producing the 'least possible number of coffees with the Rio or harsh flavour'. He says that 'it should not be forgotten that there exists a very large body of consumers which prefers the cheap Rio coffees and does not wish to change to milder and more expensive coffees'.

One of the first steps was to eradicate the opinion widely held that the Rio

flavour was due to the nature of the soil. This was done by directing planters to send samples of coffee treated in various ways to the Research Centre in 1931.

Bally gives a long account of the different samples tested, and of the results when coffee had been prepared in different ways. As might be expected, whenever ripe cherry was picked and dried properly without a prolonged fermentation, a 'soft' grade of bean was produced, and whenever the ripe cherry was pulped, and the parchment fermented and treated by the recognized wet method, a good mild grade was obtained in regions which habitually produced 'hard' coffee with the Rio flavour. The preconceived belief in the influence of the soil was thus finally overthrown.

It was concluded that it was always preferable to prepare coffee by the wet method, though it was realized that enormous difficulties would arise if such a radical change were to take place in the coffee industry of Brazil. There was the provision of pulpers for the vast number of small holders, and if ripe coffee were picked, this would mean advancing the time of harvest to take place before the rains ended, with subsequent difficulties in drying. Difficulties which have been overcome by degrees in countries producing coffee on a much smaller scale appeared too big for Brazil to tackle in face of conservatism and ingrained custom.

'Red herrings' were therefore drawn across the picture to distract attention from the acceptance of defeat. The fantastic idea was favoured that yeasts and organisms might be found in coffee cherry in districts producing mild coffee and that these, when added to the fermenting cherry in those districts producing the harsh Rio coffee, might contend with and inhibit the organism which produced the rank undesirable flavour.

A trial is supposed to have brought encouraging results when yeasts said to be capable of imparting a mild flavour to the coffee were used. The 'noble moulds' were sprayed on the cherry in a sugar solution, and a beverage prepared from beans from sprayed trees was said to have lost the Rio taste. There were two hypotheses, namely, that the secretion of the resulting ferment while the cherry was drying penetrated the beans and provoked a mild flavour, or, that the 'noble moulds' inhibited the activities of other organisms responsible for the Rio flavour.

These results were never confirmed or followed up, and the claims made tended to deter a sounder progress towards developing the wet method of preparation. Though more planters are pulping their coffee and producing mild coffee today, 80 per cent of the coffee produced in several States is still 'hard' coffee.

In fact, investigational work along similar lines was later carried out in Kenya.[14] An analysis of a total of 120 liquoring reports showed that, under the condition of the trials, the addition of prepared cultures to pulped coffee and the spraying of sugary solutions of such cultures on to picked cherries, and to ripening cherries on the trees, had no effect whatsoever on the resultant liquor of the coffee.

INTER-CROPPING

When, in the past, prices have dropped so low that it has been considered not worth while to pick the coffee, other crops such as maize and cotton have been inter-planted. Such crops are often inter-sown in young coffee, this

being facilitated by the wide spacing, and they have done much to impoverish the soil and cause erosion on the steeper slopes.

PESTS AND DISEASES

Of pests, the most serious are the coffee-bean borer *Stephanoderes hampei*, the larvae of several stem-boring beetles, and nematodes. The introduction of parasites to defeat the bean borer has met with only partial success, and the incidence of the beetle is much encouraged by the method of harvesting. A proportion of the cherry coffee is allowed to dry out on the trees; some of it falls, particularly if there are heavy rains, and dried cherries are lost and lie neglected on the ground forming breeding places and a carry-over for the pest. The planters are afraid to plant shade in case this encourages the beetle, though it may also provide better conditions for the parasites.

Nematodes may have been encouraged by the practice of inter-cropping in the early years soon after land was planted with coffee. They should not be troublesome if all the new land was planted more closely, shaded, mulched and used for growing coffee alone.

Along with all the other Latin-American countries, Brazil is fortunate in having escaped the leaf rust disease *Hemileia vastatrix*. Since the coffee is not particularly well grown, and is unshaded, the probabilities are that leaf disease would be cataclysmic should it ever enter Brazil. The authorities are worried and exercise strict precautionary measures to prevent its introduction from elsewhere. One wonders if the present arrangements will suffice, however, in these days of trans-oceanic air transport. It would seem most advisable to introduce and start propagating some of the 'Kent's' strains of coffee which are largely resistant to this disease. The belief that the temperate climate or some other factor in the environment is the reason for the absence of the disease is wishful thinking.

COLOMBIA

Colombia is second to Brazil in the world production of coffee. She is of first importance in the production and marketing of mild Arabian coffee, and can be said to be Brazil's chief rival for supremacy. The export of coffee is now some 75 per cent by value of all her other exports so that the product is a cardinal factor in Colombia's economy.[27]

Though coffee was first exported in 1834, the industry has developed mainly during the last fifty years with new planting increasing during recent decades.[32, 33] The cultivation of coffee spread gradually during the nineteenth century through the Departments (districts) of Santander, Antioquia, Caldas, and Cundinamarca, from the Department of Norte-de-Santander where it was first introduced. Progress was hindered, and still is hindered by lack of transport facilities, and there was no large-scale cultivation in the Department of Antioquia until the railway was constructed from Medellín to Puet Berrio. One might say that the main arteries of transport are provided but that feeder roads are either poor or non-existent in many of the coffee-growing localities.

Though the low coastal lands are tropical and too hot for coffee, almost any climatic environment may be found in the Andes where the soil is volcanic and where most of the coffee is grown at altitudes between 3,500 and 6,500 feet.

The Magdalena river has been the main means of transport, for it is navigable for 700 miles from the coffee port of Barranquilla on the Caribbean Sea, and along it are found many of the great coffee markets and preparation centres. Traffic on the river has been declining, however, because of silting, labour difficulties, and competition with rail and road transport.

The two most important ports are Barranquilla on the Atlantic coast and Buenaventura on the Pacific. Increased road transport is favouring the Pacific port which is also connected by rail with the districts of Valle and Caldas. The coffee producers are tending to avail themselves of lorry services taking goods into the mountains and which formerly returned empty to the ports and railway sidings. The single-track railway finds difficulty in coping with the traffic and there is often congestion at the port with delays to shipping.

Within the coffee areas many of the roads are not metalled and they become almost impassable during the wet season. A great deal of mule transport is used for delivering the cherry to preparation centres, and here and there aerial ropeways have been installed. Bogotá the capital lies in the heart of the mountains at an altitude of 8,600 feet.

The principal coffee areas are now found in the Departments of Antioquia, Cundinamarca, Tolima, Caldas, Santander, Norte-de-Santander, Cauca, Magdalena, Valle del Cauca, Boyaca, Narino and Huíla all at high altitudes, and the growers are united by the National Federation of Coffee Growers which is said to be an example of strength through unity to other branches of Colombian agriculture.

Unlike in Brazil, though there are a few large, prosperous, and well-managed plantations, most of the coffee in Colombia is grown on small peasant holdings among other crops and under mixed shade. Wickizer[33] states that some 87 per cent of all the Colombian plantations, which number about 150,000, have fewer than 5,000 trees, i.e., 16 acres, and only 0·2 per cent have over 100,000 trees. A study of 30 plantations in the regions of Chinchina and El Quindio[15] in 1949 showed that about 39 per cent of the orchards had 7 acres in production, 25 per cent averaged 17 acres, 21 per cent had 29 acres and 15 per cent reached 70 acres.

Most of the cherry from the small growers is delivered and sold to central 'Beneficios'. These are planters who grow coffee and own a large well-equipped factory for the preparation and curing of coffee, or they are traders similarly equipped who prepare the coffee for export. Almost all the coffee is washed and prepared by the wet method. It is of good quality mild coffee and the best sorts of world-wide renown are sold under the names of Medellins, Manizales, Armenias, Bogotas and Bucaramangas.

The coffee seedlings are planted when they are 1 ft. 6 in. tall, and since the holdings are small they are spaced and cultivated in various ways. In general the spacing is from 12 to 15 feet apart and though there is often very little pruning done,[31] the trees are not permitted to grow more than 6 to 7 feet tall. Fermentation of pulped coffee takes from 12 to 15 hours and it is usually dried on barbecues or by mechanical means.

When a large number of peasant land holders and small farmers plant a crop such as coffee extensively, and without much guidance, throughout a mountain range, they take their cues in everything but the choice of land from the growers who have successfully established coffee plantations in the past. In choice of land, they are bound by the locality and environment in which

they live. The many aspects and contours of the Andes mountains can be imagined, and the industry must, therefore, have been developed by trial and error.

Even so, the population would acquire knowledge of where best to plant coffee, since they would learn by the failure or successes of their acquaintances. Ultimately the coffee would succeed and become established where its correct, or nearly correct, environment happened to be.

This is a climax which does not arise until all the marginal plantings and failures have disappeared, and until that climax has been achieved it is difficult to speak with accuracy of the conditions of climate and soils where the coffee is being grown. It is said, for instance, that the temperatures range from 60° to 70° F. and the rainfall from 46 inches to over 100 inches per annum,[10] but meteorological recording stations are few and far between.

It will be seen that exports have steadily increased during the last few decades without the fluctuations which are peculiar to a mature industry, and, as much of this production will have come from young plantings, the failures have probably been masked.

Not until that climax has arrived will it be possible to see whether the peak production figures can be maintained. With a multitude of small growers there are many influences which affect production. Firstly, there is a rhythm of care and neglect aligned with a rise and fall of prices; there is the danger of production falling on account of the deterioration of the soil due to erosion or malpractices; and conversely there may be increased production from much the same area of land when teaching and better methods are ultimately adopted.

It would be difficult to say whether Colombia has reached a peak in production to be followed by a decline, or not. When a graph line of production rises as steeply as it has done in Colombia, it is usual for it to reach a peak and then fall away to a succession of ups and downs, the mean of these still slanting downwards until, with sounder experience and extensive teaching, the graph line begins to ascend again.

According to Scopes[27] and other authorities, the export of coffee from Colombian ports increased steadily and somewhat rapidly by almost a million bags of 60 kg. weight every five or six years until the 1946–47 season. On account of higher prices during recent years the value has increased in a more startling fashion.

COFFEE EXPORTS[27]

VALUE IN £1000

1938	*1942*	*1946*	*1947*
10,141	20,416	38,328	48,540

EXPORT BY VOLUME[27]

1,000 BAGS OF 60 KG.

1946	*1947*
5,662	5,339

The annual post-war export of approximately 5½ million bags represents an increase of about 70 per cent by volume over the exports of 1934. Beyond this, it appears that the internal consumption during 1946 was estimated at about 426,383 bags of 60 kg.

VENEZUELA

The Andes mountains curve into the western part of Venezuela in a north-easterly direction, and their eastern slopes may be called the watershed of the Orinoco river. The highest peak is 16,000 feet.[19] Coffee is grown throughout the mountains in favourable localities, and also on higher land in the coastal districts north, as far as the State of Sucre opposite Trinidad and inland in the State of Bolivar.

It is in the region of the Andes that the best coffee is grown, since it is here that the higher altitudes give the temperature and moisture conditions for healthy growth. There is again a great variety in the environments chosen by the smaller planters, for though the temperatures are said to average 60° F. minimum, and 77° F. maximum, the extremes are as low as 46° and as high as 90° F. In Caracas, which is in the centre of one coffee-growing region, the rainfall is only 29 to 30 inches.[10] The ideal climate is said to be found at altitudes between 3,250 feet and 6,500 feet, where the temperatures average 60° F. minimum and 70° F. maximum, and the rainfall varies from 46 to 113 inches.[10]

The first experimental planting of coffee was carried out by Spanish Jesuits in 1730 when they tried to grow it in the Orinoco valley. Subsequent attempts were made at Mérida in the eighteenth century and Fray José Antonio Mohedano introduced and cultivated 6,000 plants in Chacao in 1784. Following his success, the cultivation of coffee spread to many other States in neighbouring regions. By the end of the century exports had become considerable though the most rapid development took place in the latter half of the nineteenth century and onwards to the year 1920.

There were then successive setbacks, and low prices in 1928 hit the industry very badly indeed. A National Coffee Institute was founded in 1935 but was liquidated in 1943. From a peak production in 1920 a gradual decline began which reached the low level of 550,000 bags in the seasons 1942–43 and 1943–1944, a yield which was the smallest for fifty years. A recovery began in 1945–46, and by the 1946–47 season, 800,000 bags were being produced. In the 1949–50 season a record crop was gathered in the state of Táchira in the Andes. This coffee was of high quality and sold for better prices than the best Brazilian, and only slightly less than that for the best Colombian coffee.

Both the growers and the government had been perturbed at the decline in production. There were several reasons. Coffee grown in wrong environments declined in health after the first crop and was ultimately abandoned; soil erosion was followed by soil deterioration, which had never been combated; methods of cultivation and of pruning were often poor, seed selection was neglected, communications were poor and there had been a lack of modern equipment.

The Venezuelan Chamber of Agriculture recommended the establishment of fixed standards for exported coffee as a means of improving the quality, because the methods of preparation left much to be desired until com-

paratively recent years. The standards suggested were (*a*) Fine washed, (*b*) Ordinary washed, (*c*) Good unwashed, (*d*) Inferior unwashed.

Results showed that the campaign for the improvement of prepared coffee had been successful. In 1939 only 49 per cent of Venezuelan coffee was treated by the wet method, but by 1949 the percentage had risen to 83.[19 31 32]

The principal producing districts are Maracaibo, Puerto Cabello and Caracas. The States having the greatest production, however, are Táchira, Trujillo, Mérida, Lara Sucre, Miranda and Aragua.

Production in thousand bags of 60 *kg.*	
1937	1,242·6
1945	968·9
1946	750·9
1947	740·7
1948	890·0
1949	844·6

Coffee is Venezuela's most important crop. Until the season 1924–25, it was the most important export, though nowadays petroleum takes first place. The market names for the best grades of coffee are 'Washed Caracas' and 'Meridas'.

DESTINATION OF EXPORTED COFFEE, 1949

Country	*Bags of 60 kg.*
U.S.A.	330,326
Holland	11,149
Canada	7,456
Belgium	7,167
Syria	4,585
Italy	3,336
Norway	1,600
Chile	505
Switzerland	300
Trieste	219
Dutch Antilles	168
Denmark	52
Germany	35

ECUADOR

Ecuador is not a prosperous country. Most of the inhabitants have a low standard of living, communications are poor, and information and statistics are very difficult to obtain.

Coffee is the third most important product exported after cocoa and rice, and being followed by bananas. There are three zones where the coffee is to be found, viz., the Sierra or main ridge of the Andes mountains up to 12,000 feet, the western coastal plain, and the 'Oriente' or upper Amazon basin to the east.

The crop is grown in a very primitive manner. Growers in the region of Jipijapa in the Province of Manabi, and Santa Rosa in the Province of El Oro, have been the most progressive in regard to pruning and planting, and the coffee from Jipijapa is mostly prepared by the wet method though a great deal of that harvested elsewhere is unwashed. Almost 9,000 metric tons are

produced annually of which approximately 8,000 are exported, mostly to the U.S.A.[5 32]

Peru

The country possesses some coffee land, mainly in the mountainous regions to the north, in the departments of Piura, Lambayeque and Camjamarca and also more central land in the districts of Huanuco, Junin and Ayacucho.

Coffee is grown nowadays as a minor crop for domestic consumption alone since exports were banned in June 1947. The average production is about 80,000 bags each year of Arabian coffee. It is cultivated by smallholders at altitudes from 1,500 up to 4,500 feet in a somewhat primitive fashion.

British, Dutch, and French Guiana

It was through French and Dutch Guiana that coffee entered Brazil to start the important industry that exists today. At first, Arabian coffee was grown, but in general these countries are too humid and hot for this species, so that robusta and in particular Liberian coffee have taken its place. Nowadays a few thousand hundredweights of robusta and Liberian coffee are exported to France and Scandinavian countries.

Panama

Panama does not have much land suitable for successful coffee cultivation and the little that is grown is sold and consumed locally.

Costa Rica

The country is the second smallest in size of the five Central American States, and the population numbering about 869,000 is the smallest of them all. The economic life is most active on the central plateau at an altitude of 3,500 feet, an area renowned for its coffee, and where the bulk of the population is concentrated in the districts of Cartago, Heredia and Alajuela within a ten-mile radius of the capital of San José.

The principal exports are coffee and bananas. Coffee is traditionally the principal agricultural product and it is more important than the banana industry, not only because the exports are larger, but because the coffee industry employs more people, produces more money for exchange and has a wider effect on the general economy.

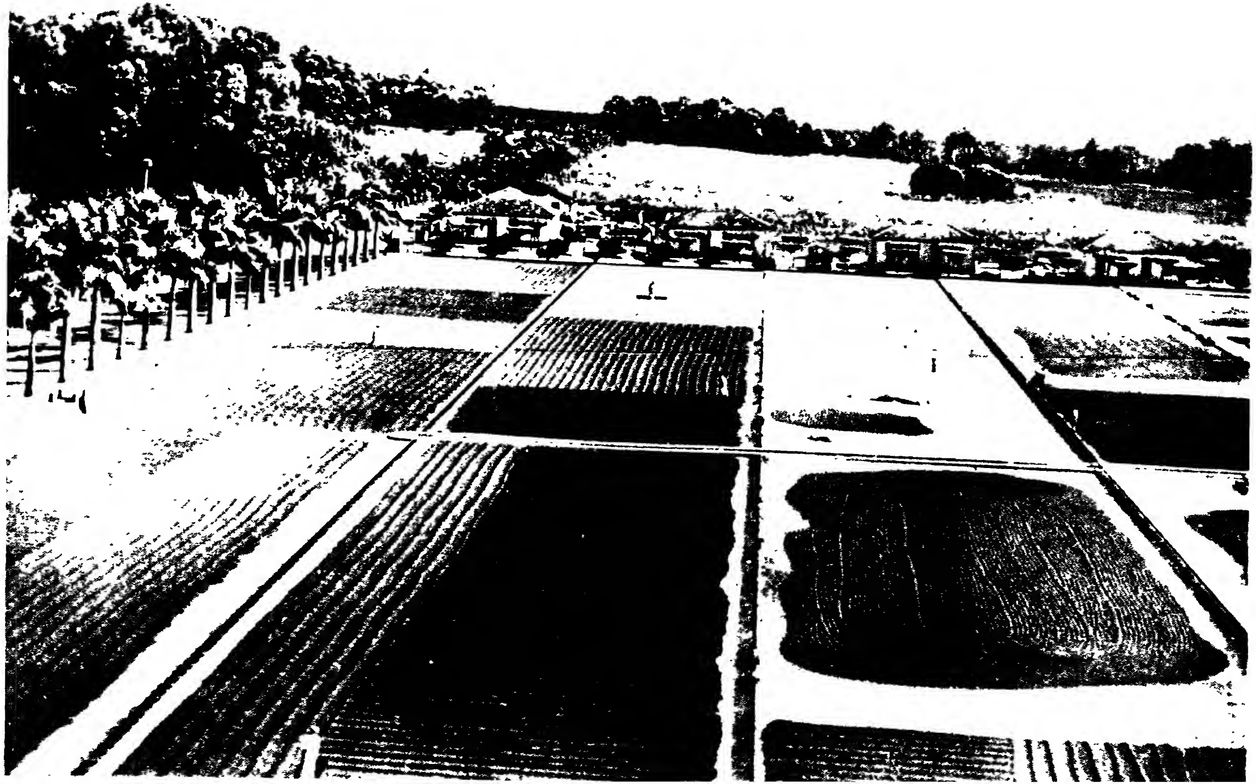
The coffee grown is of the Arabian kind, the principal varieties being var. *arabica*, var. *bourbon* and cv. 'maragogipe'. There are some large and well-managed estates and also a number of smallholders whose cherry coffee is sold to the larger estates and to the coffee exporters who compete for their supplies, and process the coffee by the wet method in a modern and up-to-date manner. Indeed, Costa Rica was one of the first countries in the Western Hemisphere to use coffee-cleaning machinery.

The mean temperature of the central plateau is 67° F. Though there is a wide divergence in temperature, often near frost, and also as high as 96·8° F.,[10] the fertility of the soil and a rainfall of 81·12 inches appear to be beneficial factors responsible for success. It is a country where the vogue of

By courtesy of the Brazilian Government Trade Bureau

An Arabian coffee plantation in Brazil The trees are almost twice as high as a man

PLATE LXX



By courtesy of the Brazilian Government Trade Bureau

A large 'barbecue' drying ground for coffee in Brazil. Men can be seen turning and ridging the drying coffee, first one way and then the other. Weather conditions at harvest permit drying in the open

'candelabra' pruning has persisted.[17, 18] It is a complicated system which has not caught on elsewhere, but it is an indication of the care with which coffee is cultivated and treated. It is all shaded, and often inter-planted among bananas.

The cultivation methods are by no means perfect. Greater attention might be given to the control of erosion; it would be better if the nursery plants were planted out when they were much smaller, and the castor-oil plant is not the best temporary shade to use. Moisture conservation by mulching and a closer spacing than 11 × 11 ft. would be of benefit, as would also a simpler method of pruning.

However, the larger estates are most efficiently run, especially the handling of the coffee which is picked into baskets when ripe and usually transported to the central factory by gravity trucks or flumed water.[11]

The prepared coffee, produced in bulk by the various factories, is some of the finest mild coffee in the world. During the first fifty years (1800–50), Costa Rican coffee was all exported to South America. In 1850 shipments began to London, and from then onwards until World War II, about 70 per cent of the exported coffee was taken by the United Kingdom and financed by merchants in London. Nowadays the Costa Rican Central Bank has a greater share in financing the industry. The bulk of the coffee went to the United States of America during the war, but more and more of it is now being exported to Europe, where the Netherlands was the chief buyer in 1952.

During the ten-year period beginning in 1935 the annual production averaged 400,000 bags. There was a bad season in 1945–46 when the yield dropped to 267,770 bags, but there was a steady recovery since then until the 1952–53 season when 477,000 bags of 60 kg. were harvested. The acreage cultivated has never varied very greatly over a long period of time and the authorities hope to double the present output within the next few years by the use of fertilizers and modern methods of production despite a poorer crop in 1954 due to the vagaries of the weather.

RECENT EXPORTS IN THOUSAND BAGS OF 60 KG.[13]*

1951	*1952*
316·3	353·3

DESTINATION 1952

Country	*Thousand bags of 60 kg.*
U.S.A.	216·8
Holland	47·1
Italy	29·4
Germany	16·1
Switzerland	15·9
Belgium	12·9
Canada	7·7
Sweden	4·0
U.K.	2·0
Others	1·3

*Figures based on tables given in the *Overseas Economic Surveys*, Costa Rica, H.M.S.O. 1954.

Nicaragua

The largest of the Central American countries with an estimated area of 57,145 square miles, Nicaragua lies entirely in the tropics. The climate varies widely according to altitude so that the mean temperature may be 60° or as high as 96° F.

Though gold comes first, coffee is the most valuable agricultural export, the bulk of it going to the United States. Coffee was first cultivated between the years 1860–70, though it was never of much importance until the present century. The productive districts lie round Manague, which is now the capital, and in the districts of Carzo, Matagalpha, Jinotega and Nieva Segovia. The first two regions are between the lakes and the Pacific, not far from the coast, while the others are in the mountainous northern area where the higher-altitude coffee is produced.

In general a good crop is expected every three or four years,[32] which is indicative of over-bearing and recuperative periods. Exports have declined markedly in volume since 1940, though 1948 was a good year. Following this, in 1949, the crop was exceptionally poor. Whereas in 1940 the exports amounted to 15,299 tons of clean coffee, the recent figures do not amount to more than 6,839 tons. Though Matagalpa coffee has achieved some distinction in world markets, the coffee producers in general lag behind their Central American competitors in production methods, and it is fortunate for the country that the increased prices of recent years have made up for the shortages in volume.[28]

El Salvador

The country is small and densely populated with most of the arable land already developed. Considerable areas of the country are mountainous, and the land which has hitherto been unused is of poor quality and unsuited to cultivation. Somewhat primitive and improvident methods have led to heavy soil erosion which continues to be one of the chief causes of soil and crop deterioration. A National Institute of Agronomy was formed under the Point IV Programme of the U.S.A. to assist in introducing better methods of cultivation and soil management. There are numerous smallholders, and a few progressive farmers who own the larger estates.

While a number of excellent roads exist, and others are under construction, the feeder roads to many of the villages can only be called mule tracks. Labour is cheap, but skilled labour is scarce.[12]

Coffee was introduced to El Salvador from Guatemala in 1866 and the varieties chiefly grown are *C. arabica* var. *arabica*, and var. *bourbon*, the first to the extent of 75 per cent and the second 25 per cent.[22] Bourbon coffee is said to do better at the lower altitudes.

The regions where coffee is grown may be divided into three. (*a*) The coastal region up to 2,600 feet, where the average temperature is from 70° to 82° F.; (*b*) a mountainous and intermediate region up to 5,000 feet, where the temperature average is from 57° to 70° F.; (*c*) An upper region over 5,000 feet where the temperature range of 40° to 60° is too cold for good growth.[20] The rains of El Salvador and neighbouring Nicaragua are unevenly distributed because they fall heavily in one season and are followed by at least three months of dry weather from January to March. For 23 years there

have never been more than 3 days of rain during this period, totalling less than 1 inch.[10]

The coffee is shaded by mangoes, avocadoes, bananas, and species of *Inga. Gliricidia sepium* is used to a large extent. In 1938, about 70 to 75 per cent of the coffee was prepared by the wet method and the remainder by the dry.[22] Pruning is somewhat primitive and often results in umbrella-shaped trees, which is indicative of die-back and probably brought about by over-bearing and lack of moisture during the dry season.

El Salvador ranks as the third-largest producer and fourth-largest exporter of coffee in the world. For many years coffee has accounted for nearly 90 per cent by value of El Salvador's total exports[12] and the country continues to enjoy great prosperity thanks to good crops and high prices.

The crops fluctuate, and a certain amount of retrogression brought about by soil deterioration and a falling off in the health of the older plantings, has probably been hidden by new plantings constantly reaching the bearing age. Since most of the arable land has been taken up, the planting of coffee has now about reached its maximum, and there is likely to be a slow decline in production rather than any spectacular increase.

The best customers for the exported coffee during recent years have been the U.S.A., Canada, Sweden, Chile and Switzerland.

EXPORTS IN THOUSAND BAGS OF 60 KG.*

1950	*1951*	*1952*
1,155	1,098	1,115

*Figures based on tables given in the *Overseas Economic Surveys*, El Salvador, H.M.S.O. 1953.

HONDURAS

Honduras is not a very important coffee-growing country. There are several reasons: labour is scarce, communications are poor and interests are shared in other crops such as bananas. Production has, however, increased during the past decade, and the coffee is grown mostly in the highlands of the interior in the States of Santa Barbara, Copan, Choluteca, Cortez, La Paz and El Paraiso at altitudes of between 1,500 and 4,000 feet. The following figures are supplied:[32]

Year	*Production in bags of 60 kg.*
1937/38	40,000
1944/45	116,000
1946/47	160,000

GUATEMALA

The country has two seaboards, i.e., the Atlantic and the Pacific Oceans, and the most important port of Puerto Barrios has its outlet into the Atlantic through the Gulf of Honduras. Its area is 45,452 square miles and the

country is divided longitudinally by the 'Cordillera' with its many volcanoes. This mountain range lies nearer the west coast, but the more important rivers flow towards the east.

The country is situated mainly in the sub-tropical belt. The western side is well-watered and holds the greater part of the population. There are two distinct climates covering the coastal zone: on the one hand where it is tropical, and on the other the higher altitudes where the climate is more equable. Roads are fairly extensive in the western zone, but the eastern side is poorly supplied with communications.

About one-fifth of the total cultivated area is devoted to coffee production which comprises about 75 per cent of the exports. Most of the coffee is produced in the western zone, though quite a lot is grown round Coban in the Baja Verapaz region.[2]

The varieties of Arabian coffee grown are chiefly the 'nacional' i.e., var. *arabica*, var. *bourbon*, and cv. 'maragogipe'. Bourbon coffee is mostly grown at the lower elevations as the bronze-tipped coffee is considered more resistant to cold.[18]

A triangular spacing of 12 × 12 ft. is favoured in Guatemala and many practise the 'candelabra' system of pruning whereby the stem is topped near the ground to produce two leaders. These are topped again to produce a total of four, and again to produce eight until the bush has reached what is considered by the planter to be a convenient height. When the trees begin to bear, the weight of fruit bends the branches outwards to facilitate harvesting. The system is difficult to explain and to carry out when the older stems must be sacrificed to allow for rejuvenation. The rainfall is heavy, and while the wet season lasts from May to October, there is a considerable period from November until April when conditions might be said to be too dry to be ideal.

The coffee is usually shaded. The methods of cultivation among the smaller land-holders leave much to be desired and the cherry is mostly treated at central factories, where British-made machinery is greatly in demand.

Guatemala is fourth in coffee production but third in exports among the Latin-American countries. Production amounted to about 51,000 metric tons in the 1946–47 season.[32] The best-known coffees from Guatemala are 'Cobans' and 'Antiguas'.

MEXICO

Coffee is now one of Mexico's major exports and by all accounts new plantings have been extensive during recent years. Furthermore the 'Comisión Nacional del Café' has been taking a great interest in teaching better methods of cultivation and production among the many smaller growers.

The country now ranks fifth among the coffee-producing countries of Central America on account of increases in crop yields during the last two decades. Production has amounted on the average to just over 900,000 bags, but exports have averaged only 530,000 bags because internal consumption has been rising of recent years.

The states of Vera Cruz, Oaxaca and Chiapas can be said to comprise the real coffee area where some 85 per cent of the coffee is grown, and the remainder is produced in Puebla, Colima, Michoacan and Tobasco States. The chief market centres are Jalapa, Córdoba, Tapachula, Oaxaca and Mexico City. Coffee from Tapachula was well known on the London market

By courtesy of the Brazilian Government Trade Bureau

Arabian coffee trees in Brazil Note the tall close growth

PLATE LXXII

before World War II and the sorts best known are 'Coatepec', 'Huatusco' and 'Orizaba'.

The coffee grown is mostly Arabian of var. *arabica*, var. *bourbon*, and cv. 'maragogipe'. It is planted chiefly under shade trees of various kinds on high mountain slopes, and the majority of the plantations are situated at an altitude of between 1,640 and 4,920 feet.[11] The best localities are said to be those at altitudes from 2,600 up to 3,250 feet, where the temperature does not fall below 50° F. In Vera Cruz, the major producing State, the rainfall is from 58 to 97 inches per annum, while at one of the plantations in the State of Chiapas the annual rainfall is said to reach 203 inches.[10] The coffee regions are sometimes subject to hailstorms and severe droughts, but immunity from harm is gained by using shade.

Erosion has been the chief cause of soil deterioration, because no attempts were made to terrace the land on steep slopes until very recent years. The smaller growers have neglected pruning in the past, so that their trees made a natural growth with multiple stems, and as these bent over with the weight of fruit new suckers grew in great numbers bunched together and overdrawn. Teaching aims at thinning out these abundant growths on all the older plantations. The newer plantations are being developed along modern lines.

With regard to the older holdings among which pruning is now being taught, it is interesting to note that many of the trees are more than fifty years old and still bearing amazing crops. The agobiada system of pruning is the one favoured.

From all accounts a considerable expansion of coffee production can be expected. Recent production and export figures are given as follows.[29*]

Year	*Area planted in hectares*	*Production (in thousand*	*Exports bags of 60 kg.)**
1947 ...	135,405	923	—
1948 ...	135,541	886	—
1949 ...	144,721	984	817
1950 ...	—	—	768

*Figures based on tables given in the *Overseas Economic Surveys*, Mexico, H.M.S.O. 1953.

Haiti

The Republic of Haiti is the western portion of the largest island in the West Indies, which it shares with the San Domingo Republic. The area is about 10,700 square miles and since four-fifths of the country is mountainous it is known as the Land of the Mountains. These mountains rise to an altitude of 9,000 feet in the south, 7,000 feet in the centre and 5,000 feet in the north, while in between lie several large and small plains.

The country is troubled with over-population, a shrinking of its natural resources, illiteracy and lack of communications.

Coffee is the principal product but there are very few large plantations and most of the coffee is permitted to grow in a semi-wild state by the small land-holders who rarely give it any care or cultivation.[21] The people pick the coffee and sell the cherry to certified factories where the methods of preparation are approved, and curing is completed by the exporters who store and ship principally through Port-au-Prince which is the important port. Since

1939, 19,000 cement-drying platforms have been installed under the co-operative law of 1939, for the use of individual farmers.[32]

Most of the coffee is grown at an altitude of 1,500 feet. Production has decreased because, prior to 1930, coffee accounted for 70 per cent of the total exports. In 1939 it dropped to 52 per cent and in 1940 to only 38 per cent.

EXPORTS IN THOUSAND BAGS OF 60 KG.

Year	*Approx. exports*
1932/33	608·3
1944/45	499·5
1945/46	404·7
1946/47	410·9
1947/48	378·8
1948/49	463·7
1949/50	437·4
1950/51	423·7

N.B.—It will be noticed that there has been a tendency for production to revive during recent years on account of higher prices.

SAN DOMINGO

Only a very small part of the available coffee land is under cultivation, and a fair proportion of the trees now planted are still quite young. Seed was introduced as early as 1715 and by the middle of the nineteenth century San Domingo coffee had achieved importance in the world's coffee markets. Then came a period of political troubles and decline at the turn of the century until, after World War I, a recovery took place and great strides were made in coffee production, doubtless still further encouraged by the recent years of high prices. Production figures are given as follows:[32]

Year	*Bags of 60 kg.*
1919/20	10,000
1944/45	500,000
1945/46	255,000
1946/47	325,000

Since the growers have much to learn concerning the correct cultivation of coffee, and choice of environment, it is to be expected that bumper crops and good years assisted by the first crops of new plantations, will be followed by exhaustion and periods of recuperation.

CUBA

Coffee is grown here and there throughout the island of Cuba, but it is the chief crop of importance in the Oriente Province at the eastern end of the island and it is also grown to a considerable extent in the Central Province of Santa Clara and in Pinar del Rio. Exports were banned in 1945 because the domestic consumption had increased during the war until it began to exceed the supply. Efforts were made to increase production and licensed exports have recently been resumed.

Puerto Rico

Coffee was an important industry before the hurricanes of 1926 and 1928 which did immense damage to the plantations. Exports then amounted to more than 300,000 bags of 60 kg. Recovery was severely curtailed when the European markets became closed to Puerto Rico during World War II so that exports were negligible.

Nowadays the industry is being rehabilitated and a great deal of research has been carried out at the agricultural experiment station attached to the University of Puerto Rico. A number of species and varieties of coffee have been introduced. Arabian coffee is favoured and the strain grown is known as 'Porto Rican'.[20] This is thought to have matured from the 'nacional' coffee of Brazil, i.e., *Coffea arabica* var. *arabica.* Bourbon coffee is also grown and several seed strains from Java.

Coffee soils in the island vary and are known as the 'Coloso clay' which is poorly drained during the rainy season and has an acidity value of *p*H 4·6, and the 'Catalina clay', one of the most extensive lateritic soils found on the island, which is said to occur where the rainfall is 71 inches or more. It, too, is acid, with a *p*H value of 4·98.

The coffee is generally planted at a spacing of 8 × 8 ft. under mixed shade. Species of *Inga* are often used. On account of the nature of the soil most of the coffee roots are found in the top twelve inches of soil, and authorities such as Guiscafre and Gomez, writing in the Agricultural Journal of the University, advise the use of shade trees with deep roots.

Hawaii

It is stated that Hawaii produces annually about 10,000,000 lb. of raw coffee on 5,000 acres.[8] Though a yield of nearly 18 cwt. per acre might be possible under experimental conditions on the Hawaii Experiment Station, the author would cast grave doubts on such a claim concerning a widespread area of commercial planting. The fault may lie in computing the acreage.

The Arabian coffee is mostly grown in the Kona district, hence the word 'Kona' is given to the coffee exported from the island.

A great deal of the experimental work which has been accomplished, has concerned investigations regarding nutrients, shade and seasonal growth in relation to cropping and over-bearing. Die-back and irregular yields appear to have been the chief trouble.

It is said that there is an excess of sunshine with a minimum of moisture at the lower altitudes, with a surplus of rainfall and limited sunshine at the highest levels where the coffee is grown.[26] Doubtless, warm temperatures and the lack of a sufficient and evenly distributed rainfall are the root causes of the die-back.

The rainfall which is related to the seasonal fluctuations in yield does not occur, it is said, in the year of blossoming, maturing, and the harvesting of the crop. It is the rain which occurs during the year in which new fruiting wood is being produced which affects the succeeding year's yield of coffee.[9] This seems a strange finding, since in most coffee-growing countries the new growth for the next season's crop takes place annually to coincide with flowering, cropping and the wet season.

During tests with fertilizers, when treatments were at the rate of 80 lb.

nitrogen, 80 lb. potash and 80 lb. phosphorus (the annual rate being 160 lb.) no significant differences were obtained until the third harvest, but from then onwards very significant increases were noted in the plots receiving potash.[8] This confirms results elsewhere recorded in previous chapters. A long delay appears to take place before potash takes effect.

Results of analyses of nutrients found in the leaves suggest that the yield may be influenced by the potassium content of the leaves during the previous year. The growth of laterals may be curtailed by a potassium deficiency brought about by the withdrawal of potassium to the fruit.[7] We are thus brought back to over-bearing as the root cause of uneven cropping, though it is suggested that regular applications of potash may assist new laterals to grow.

It should be noted that much of the coffee in Hawaii is grown without shade.

West Indies

FRENCH WEST INDIES

The amounts of coffee grown in the French West Indies in the islands of Guadeloupe and Martinique are not very large. It will be remembered that the first planting material to reach the Western Hemisphere was that planted and propagated on the island of Martinique.

BRITISH WEST INDIES

In general the smaller islands are not easy to cultivate on their higher slopes, since they are often steep and rugged. At the lower elevations and along the coast lines the climate is humid. Temperatures rise from about 70° to 85° and 90° F., and the rainfall is approximately 70 in. per annum.

In other words, the climate near sea level is rather too warm for Arabian coffee.

For many years other crops have been grown for preference in most of the islands. Sugar, bananas, cacao, nutmegs, cotton, limes and arrowroot are some of those grown, all indicating by their success that the climate is too warm for Arabian coffee. On the other hand, the conditions are suited to the cultivation of robusta coffee so that flourishing industries have sprung into being during recent years.

JAMAICA

Bronze-tipped Arabian coffee was first planted in Jamaica in 1730, and a flourishing industry began in the Blue Mountain region. Planting material taken via the Edinburgh Botanic Gardens and Scottish Missionaries to Nyasaland, proved the strain to be none other than the 'nacional' coffee of Brazil or the *Coffea arabica* var. *arabica*.

Despite this, and because of the altitude and the climatic conditions pertaining to the Blue Mountains region, also the manner in which the coffee was treated after harvest, the Jamaican Blue Mountain coffee was soon renowned for quality and became recognized as the finest mild Arabian coffee in the world.

Doubtless throughout the years a local strain has developed, if not from the genetical make-up of the plants first grown, then, perhaps, by an unconscious

or natural selection as the years have passed. Seed of Blue Mountain coffee has been planted more recently in other parts of the world, for instance in Kenya, where the strain was found to differ slightly from other coffees in an inherited manner. Disappointment ensued, however, when the crops were harvested, because, although the resultant coffee was of high quality, it did not differ significantly from the best local sorts of Arabian coffee.

Since the Blue Mountain Arabian coffee survived a long period of ignorance and maltreatment, it is to be expected that the surviving trees may have been those with extra vigour. The coffee was planted on steep slopes, and the industry developed at a time when pioneer coffee planters had to discover the best methods of cultivation for themselves. They treated the coffee and the soil much as they would have treated an orchard crop in their home country, forgetting the effect that torrential rain might have on a clean-weeded soil and having no knowledge of how to stop erosion on such steep slopes.

As a result, the Blue Mountain plantings were largely ruined by erosion; the soil deteriorated and the crops declined. Today the Arabian crop is small and the product is mainly exported to the United Kingdom and the continent of Europe. It is the only coffee exported in barrels and not in sacks.

A ten-year programme of rehabilitation was begun in 1943 and the authorities have halted the decline in production. Teaching aims at bringing back the Blue Mountain plantations to a fair state of cultivation. Quite a promising robusta coffee industry has developed at the lower altitudes; government nurseries were established and in addition to the small factories owned by Growers' Co-operative Associations, two central factories for the treatment of coffee have been installed to which coffee cherry is delivered. The industry is now controlled by the Coffee Board, which continues to be the sole exporter of all raw coffee beans through the Marketing Administrator.

Of the 1952–53 crop 400 tons were sold to the Ministry of Food in the United Kingdom, under contract; the balance, including the Blue Mountain grades, was sold on the world market. The Blue Mountain crop amounted to only seventy tons.

RECENT PRODUCTION IN BAGS OF 60 KG.

Season	*Bags*
1949/50	20,052
1950/51	23,690
1951/52	16,883
1952/53	22,082

At the government nurseries everything possible is being done to select mother trees and good seed. Experimental plots of coffee have been laid down and in general the methods advised follow the research findings and modern practices of East Africa. Only in pruning does advice differ greatly because, on account of the prevalence of hurricanes, single-stem pruning is urged for all new plantings with the bushes kept as low as possible and topped at from 3 ft. 6 in. to 4 ft. tall in all exposed situations.[23]

TRINIDAD

Trinidad also produces two kinds of coffee, but, whereas the crop of Arabian coffee harvested in 1953 was about a fifth of that reaped during

the previous season and considered locally to be a failure, a record crop of robusta coffee was reaped. All available drying space was occupied and the estates having factories with artificial dryers had difficulty in harvesting and drying the crop.[4]

It appears that coffee was formerly planted in hedgerows and as a catch crop in open spaces among cacao trees. Nowadays it is being planted in pure stands on plantation lines, and it is forecast that when the present plantings come into bearing, production will be doubled. Coffee is proving to be an economic crop on soils unsuitable for cacao, and of course the recent high prices have given the coffee planters all the encouragement they needed.

EXPORT IN BAGS OF 60 KG.

Destination	*1937*	*1951*	*1952*	*1953 Jan.–Oct.*
U.K.	—	4,478	86	2,729
Canada	9,618	3,887	2,733	5,038
U.S.A.	2,518	1,763	302	1,964
Italy	—	—	7,214	5,860
Gibraltar	—	—	3,332	—
Netherlands ...	—	—	—	1,436
Others	1,115	897	322	861
Totals	13,251	11,025	13,989	17,888

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Chapter XVIII

THE ECONOMY OF COFFEE PRODUCTION

Plantation Economy

INSUFFICIENT CAPITAL

Lack of sufficient money and the inability to make the best use of land lie at the root of a great many failures.

A proper clearance of tree stumps will pay in the long run, just as solid anti-erosion measures will preserve the soil. The development of permanent water supplies at a sufficient number of points will facilitate the task of spraying. Mechanical implements will save money, as also will solid structures and proper buildings.

The aim should be at doing each job well at the proper time, but not to lose time in gaining returns. For this reason temporary structures may have to suffice at the start, and all one's efforts be directed to raising healthy coffee plants and planting them without delay in the proper manner.

It will have been noted in previous chapters how coffee trees improve in yield as they grow older, how various practices early on may lead to less exhaustion and bigger yields in future years on account of the health and extra vigour of the trees, and how gaps in a plantation will seriously affect the return per acre. A man may break his heart and his health by striving to bring an estate into bearing on too little capital, only to find that he must mortgage his property and take advances on first shipments.

It drains the strength of a plantation if interest has to be paid on loans and if these have to be paid back at a time when a proper proportion of the first returns should be ploughed back into the estate. The provision of spraying equipment is often left too late and men watch their plantation being defoliated by a pest or a disease, helpless to check the spread in time, thereby causing damage which may take several years to repair.

PRICE FLUCTUATION

At the time of writing the price of coffee is very high indeed. While such high prices last they may make many a marginal estate a paying proposition. While profits are good, that is the time to install labour-saving devices; to spend money to prepare for the day when prices fall; to treat the marginal estate so that it becomes, if possible, first-class. Block by block it may be replanted with a better strain of coffee and with better shade trees; the soil may be improved and the estate factory reorganized.

The history of coffee in any one country is strewn with records of successes and failures, with booms and slumps. During the good years when prices are high, men hasten to plant coffee anywhere and anyhow. Land values rise and good land becomes scarce. It is not an economic proposition to start planting coffee on poor land because it happens to be cheap, persuading oneself that hard work will improve it, or to plant where the environment is

totally unsuited to coffee merely because land cannot be procured elsewhere. Neither does it pay to play into the hands of local sharks and buy land at rates far above its true value.

If one starts planting at the height of a boom, that is the time for cynicism and a sour outlook, feeling sure in one's own mind that the boom will end just about the time when one's first crop is set and before it ripens on the trees. Only when prices are low, in fact at their lowest ebb, can one be truly optimistic and look forward to better days.

Coffee planting is increasing nowadays in every country where it is grown, and governments are urging the native peoples to plant in half a dozen territories. For this reason it is necessary to root out any idea that such high prices will continue steadily for many years to come. If they did it would be fortunate. Instead it is wise to assume that prices may be much less. It will then be seen that there is still a chance of making a good living provided sound practice is followed and careful note is taken of the guidance given by research. Obviously it is better to plant less and give almost individual attention to each tree, rather than to plant a vast area and treat the trees like turnips in a field.

A small-minded man relies on hope—hope that one of his football coupons will be a winner, hope that frosts may recur in the coffee estates of Brazil, or that leaf-disease may disastrously invade that country to boost up prices for the lucky ones elsewhere. A business man cannot rely on hope. He must be sure and rely upon his own efforts and businesslike appraisal of the future, ready to take advantage of high prices and be safeguarded against the reverse.

Choice of land, of environment, of soil, and of nearness to transport routes are very important, and having chosen the right place, determined to benefit by modern knowledge, a cautious man may estimate a yield of about three cwt. of clean coffee per acre in the first crop year, increasing to about an eight cwt. average when his trees are eight years old. Higher yields are possible, more especially as the trees grow older, provided the plantation is maintained in good order.

What, then, are the returns to be expected if the price dropped to £100 per ton? Perhaps £3,700 from 250 acres in the fourth year—barely enough to pay expenses. Returns will increase with fluctuations until at eight years the gross return might average £10,000 per annum. Yet the costs will be high and the net return nothing to cause elation. Everything would then depend on the cost of labour and the provisions for economical working which had been installed in the beginning.

At prices ruling at the time of writing, the return would be five times as much and no one envisages the price for best quality coffee dropping as low as £100 per ton for a considerable period of years. The world supply is finely balanced against demand, so that a good year or a bad year in Brazil might tip the scales either way. Moreover, so great is the production of Brazil that the increased planting taking place in other countries might not be felt to any great extent.

SAFEGUARDS

No matter how much coffee Brazil may produce in the near or semi-distant future, most of it will be classified as 'hard', or of inferior grade, despite the fact that it is of the Arabian kind. The people are conservative,

and though the Brazilian government may do all in its power to encourage progressive methods of culture and preparation, it may take a long while before the people and the established trade respond to make an effective change. There is a preponderance of poorer quality coffee on the markets of the world, while there is still a shortage of the best mild kinds.

Robusta coffee properly prepared by either the wet or dry method is classified as a mild coffee but even the best robusta grade is of an intermediate kind. If a slump did set in, robusta coffee would reach a low level along with Brazilian coffees, but good-grade washed Arabian coffee would resist the downward trend and always find a buyer at better prices.

Many countries are now seemingly planting more and more robusta coffee because of its stamina and freedom from troubles, relying on yields from selected strains that are heavier than those from Arabian coffee to make up for the difference in price. In fact it would be wiser to leave the planting of robusta coffee to indigenous peasant peoples whose cost of living is not so high, and whose 'overheads' do not require much capital. They can resist low prices by co-operative enterprise.

Plantation robusta at the present moment pays, but as a safeguard against the future it would be wiser to find land where Arabian coffee will grow well, to overcome the troubles which may beset a coffee of a more delicate kind, and to concentrate on producing a mild coffee of the highest quality. In other words, it is safer for a planter to grow Arabian coffee.

While mentioning co-operative undertakings, it is pointed out that these are not peculiar to peasant peoples and may well be indulged in by any class and trade. It is much safer and more economical for planters to co-operate rather than to stand alone; so much can be done. Tools and equipment may be purchased at a cheaper rate; expensive earth-moving, hole-digging and other machines may be centrally stocked and hired out to members; central curing works may be established and the whole business of marketing be taken off the planter's hands. These are just a few of the advantages of regional co-operative movements.

MIXED FARMING

Another safeguard, of course, is mixed farming—something at which every planter should aim. It is wiser to start farming and then plant up some of the choice land with coffee, rather than to plant coffee alone and put off farming to some distant date.

A planter needs crop residues such as straw and grass for mulching; a farmer needs grass for livestock. Both need manure, chiefly for the grass. An eminent scientist once wrote[5]: 'In Europe mixed rotations serve the purpose of enriching the crop land with plant foods derived from imported cattle feed. Where cattle feed is not imported, mixed farming merely moves plant foods round the farm; it cannot add to their total amount.'

If grass is grown and fed to livestock or used for mulch, one is merely removing nutrients from the grass plot elsewhere and the grass plot deteriorates unless it is manured. Grass responds to chemical manures, and it is this use of imported chemical manures that is most economical. To manure and use grass in such a manner is the best means of building up fertility throughout a holding. Grass used in rotation with crops and as a mulch between coffee trees is the cheapest method of preserving soil structure, conserving moisture

and increasing fertility. By using grass in the correct way one may build up fertility without importing cattle food.

Moreover, any farmer would consider it foolish to import fertilizers to manure and grow comparatively large acreages of grass for mulching coffee alone. There would be seasonal occasions when young grass could be grazed or turned into silage. It has to be wilted before being used as mulch. Why not use part of it to bed down animals on its way to the field? It is common practice to shake out the long urine-soaked straw from farmyard manure for mulching purposes. Even the Coffee Research Stations keep livestock.[11]

Despite the cost of devoting land to growing the material for mulching coffee, and the tasks of cutting, carting and spreading, mulching definitely increases profits in countries of short rainfall. At Lyamungu it was found that weeding costs were reduced from a 35 days' average per acre per annum for clean weeding, to 26 days under a Napier grass mulch, 8 days under banana trash and 4½ days for a Guinea grass mulch. A banana trash mulch thus saved from 27 to 30 man days per acre.

Increased yields following mulching have been as much as a hundredweight more of clean coffee per acre and there are invisible gains such as the maintenance of soil structure, extra fertility, and the health of the coffee trees. There is also a reduction of soil loss because erosion has been prevented. Demonstrations have shown that mulches have reduced soil loss from a low of 8 tons to a high of 28 tons to nil over a period of 3 years.[8]

Of course there are leguminous crops which enrich the soil in other ways, but the main object in mixed farming is to have a balanced economy. One does not necessarily have to grow crops or invest in ventures which give poor returns. In any community there is usually a demand for milk, butter, eggs and bacon. It is fatal to produce eggs in Gambia, raise pigs in Queensland and grow ground-nuts in Tanganyika as any farmer knows, and it is best not to grow coffee alone.

Tools used for one crop stand idle in season, whereas in a mixed farm they tend to be used all the year round. Buildings serve more than one purpose, labour can be switched from field to field as the necessity arises and in such ways costs can be spread. One of the drawbacks of a coffee plantation is the increased labour force which is suddenly required for harvest. All sorts of maintenance work has to be neglected when the coffee berries ripen. Power supplies stand unused after the crop has been prepared; fermenting and washing tanks and storage space are empty for half the year.

POTENTIALITIES

Potentialities depend on a man's strength, on his health, his willingness to work and his acumen. There is such a thing as having too many irons in the fire, and of taking on more than is within the power of one man to supervise with the necessary attention to detail. Much depends on whether he can employ a sound dependable foreman or manager to help him during peak periods of endeavour, or during his absences on leave or during sickness. Potentialities also depend on environment and spacing of crops.

Arabian coffee has often been spaced 6 × 6 ft. or 8 × 8 ft. apart, though the practice nowadays is to plant at 9 × 9 ft. apart, especially in regions where the rainfall is a little short. Spacing often depends, not so much on the growth

above ground as on the available moisture supply in the soil. When moisture is sufficient, coffee may be planted a little closer.

An experiment was started in Uganda in 1932 with spacings at 4 × 4, 6 × 6, 7 × 7, 8 × 8 ft. apart. By 1939 the wider spacings were producing healthier trees and heavier yields, but the early successes of the 4 × 4 and 6 × 6 ft. spacings were still being reflected in the total yields. As late as the 1947–48 report of the Department of Agriculture[9] the yields totalled 1,310 cwt. of fresh cherry per acre for the 4 × 4 ft. spacing as against 962 cwt. for the 8 × 8 ft. spacing.

It appears that the closer spacings were superior during the first three seasons and in the fourth all were equal. After the fourth season, the general yields, the health of the trees, and the costs of picking and so on were in favour of the wider spacings. It seems, therefore, that if a man will cut out half his trees at a 4½ × 4½ ft. spacing at the end of the third season, leaving them thenceforward at a 9 × 9 ft. spacing, he may reap the benefit of almost a double crop during the first three seasons. Especially might this be the case where the rainfall was adequate, since there would be less likelihood of harm to the trees that remained. If such a scheme was followed, the trees to be cut out would be best pruned to the single-stem, while those that were to remain, would be trained to a multiple-stem system.

PEASANT-GROWN COFFEE

In Uganda approximately 50,000 tons of coffee are grown by African farmers in gardens averaging a portion of an acre apiece, and in Tanganyika Territory some 12,000 tons are produced in the same way. Elsewhere in the world, large quantities of coffee are similarly produced by smallholders, and in some cases, urged by the present-day boom, governments are fostering an increased production.

Wherever peasant coffee planting is urged or practised, co-operation and control are vital necessities. It is only by devolving authority to their own associates or co-operatives that control can be decentralized and properly maintained. A small cess or subscription to such societies with a modicum of financial help from governments will establish central pulperies and curing works. Individuals who have not the financial strength to employ mechanization may then hire or claim assistance from their regional headquarters. Spraying machines and chemicals may likewise be stored in preparation for eventualities, and men trained in readiness to use them. The intellectuals tend to become the leaders, who are much more likely to obtain a hearing and create example than are alien instructors and supervisors. It cannot be too strongly stressed that a young industry should be properly organized at the beginning.

Co-operation and the building up of funds creates resiliency and better marketing facilities, price stabilization and security. It encourages an industry to move forward at a quicker pace and offers, among impecunious people, far more posts of an executive nature than can be found in towns and government offices. It helps to raise the standard of living, and when once it has been started on a sound basis there is no end to the activities which may ensue. The example of the native coffee industries of Uganda, and of the Northern Province of Tanganyika, might well be followed in other parts of the world.

One phase in the history of the progress of co-operation in the Kilimanjaro area may be of interest to record. At first, each of the several thousand growers prepared his cherry coffee in his own primitive fashion. The parchment coffee was sold indiscriminately to small traders. Some samples were sticky, dirty and not fermented; some were first class, and others were spoiled, musty and insufficiently dried. All were bulked by the traders so that the coffee was of inferior grade, and the European planters justifiably complained that the export of such coffee created a bad name for the product as a whole from the Kilimanjaro region.

The first step instituted by government was to have all the native coffee delivered at a central store, where the parchment coffee was graded, bulked, and auctioned; the growers paid afterwards in accordance with their shares which were recorded on receipt slips. At such deliveries all the dirty or musty parchment was rated undergrade and wet coffee was rejected. Within a few deliveries all the parchment coffee was delivered clean and properly dried so that most of it was termed first-grade.

Shortly afterwards the people wanted their coffee shipped to London and sold at London market rates. They agreed to wait for their proceeds and the matter was organized with the help of local agents. As a result the mark became known and the cured Arabian coffee fetched top prices on the London markets on several occasions in 1926 in competition with European-grown coffee.

Not that it was any better, or even so good. The reason for the high prices was that it was sold in big parcels of standard quality. It could be depended on, it became known, and a flutter of excitement took place in the sales room whenever a parcel was put up for sale.

The coffee emanated from east to west and from high and lower altitudes on the slopes of the mountain. Seasonal differences in the quality of the coffee of each producer were evened up by bulking, so that the quality was standardized from year to year. No matter how careful a European planter was, his coffee differed from season to season in regard to the 'on' and 'off' years of his crop. His parcels for sale were much smaller by comparison and the quality was not standardized.

In the experience of the author it is advisable to bulk the coffee produced in any one region, and to aim at a high standard of quality by the self-imposition of a very strict first grade. This is possible only by co-operation, and it pays handsome dividends when prices tend to fall. It permits the product to find a market when world supplies are greater than the demand.

INDIVIDUALISM

Large-scale planting is inclined to adopt what might be called individualism. Each man will have his own ideas about how to prune and how to treat his plantation. He tends to compete with his own neighbours rather than joining with them in competing against other countries of production. An extension officer calling at some properties is sometimes looked upon as one who has a store of 'book-knowledge' but little practical experience, whereas his constant visits to coffee plantations, and his trained powers of observation, have probably taught him more about sound practice than any individual planter in the region.

Individualism, the trying out of new methods and treatments by planters

By courtesy of the Kenya Information Office

A coffee estate at Kiambu, Kenya Colony

PLATE LXXIII

By courtesy of Public Relations Dept., Tanganyika

(*a*) Coffee being taken to grading and marketing centre, Kilimanjaro Mt., Tanganyika Territory

(*b*) Coffee at delivery centre, Kilimanjaro Mt., Tanganyika Territory

By courtesy of Public Relations Dept., Tanganyika

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themselves, is all very well in regions that lack local research establishments. The ideal is co-operation even among those who plant coffee in a big way, co-operation among themselves and co-operation with research, learning from the results of research how best to grow the crop in their particular region. Given the guidance of research, individualism becomes foolish if it is carried to the extreme.

UNSOUND SCHEMES

The author has on occasion been intrigued by the plausibility of some unsound schemes. For example, there is the idea of treating Arabian coffee as a temporary crop on low-lying fertile soil where the temperatures are too warm and where irrigation is available.

The idea embraces planting coffee seedlings in a ploughed furrow close-spaced like a hedge, three feet distant in the row, the rows six feet apart. Blocks are planted in succession for three to four years, the first block ruthlessly stumped or uprooted and replanted following its first good crop. In a warm environment Arabian coffee grows fast and over-bears its strength during its first crop in the third year, so attention is given to the control of diseases and pests, to the prevention of die-back and empty cherry by spraying and irrigation. As much of the first crop as possible is harvested, after which the trees are sacrificed or stumped for regrowth.

It is argued that scant attention is needed, no pruning and very little cost in return for the use of cheap land and a steady harvest as younger blocks come into bearing each year. A farmer who had put this into practice assured the author that he was making a handsome profit, and this was years ago when the price was a fifth of what it is today. His land was weedy and his coffee looked pale, sickly, and overdrawn, but the bean in his store looked bold enough even if it lacked colour.

Nemesis usually waits round the corner for those who tempt Providence. Diseases and pests build up despite modern controls, and effective spraying becomes so expensive that profits dwindle to nothing. Leaf disease may reach an appalling state; thrips, red spider and *Antestia* can be so bad that the venture becomes farcical. The sorry individual is disliked by orthodox planters at higher altitudes because of the diseases and pests he fosters, and because of the poorer quality coffee produced in the neighbourhood.

INNOVATIONS

Sometimes it is possible to use water to flume cherry coffee to the factory, or to use some form of light overhead ropeway to save transport. A water-wheel, if such can be installed, will provide cheap power for the factory. The use of home-made sleds to transport grass mulch to the field and the baling of the wilted grass are useful innovations.[10] It is in the realm of useful innovations that individualism can play its part in cheapening production.

MECHANIZATION

The larger the plantation, the more important it is to use mechanical implements. In so far as mechanization is concerned, when once a coffee plantation has been cleared and planted it should be treated as one would a

plantation of forest trees. Cultivation should not be necessary after the first year if the soil is kept covered with a mulch.

A mulch quickly decomposes in the tropics, however, and if alternate row mulching is adopted then the rows without a mulch will grow weeds. In such a case, while there is sufficient space between the trees, a light tractor and a very shallow cultivation may be used along the contours. At a nine-foot spacing, and with shade trees as well, the ground should soon be shaded sufficiently to inhibit weed growth, except for a few etiolated growths which are cheaper to eliminate by hand or which can be covered by the next mulch.

Mechanical ploughing and cultivating, though useful at the start, will not often be required in later years except when new blocks are planted, or when dealing with the area where mulching material is being grown. The original purchase and cost might be spread and be more worthwhile if they could find continual use on a mixed farm attached to the coffee plantation.

Light tractors will always be of use on a coffee estate, and trailers too, for the carting of mulch, compost and coffee cherry to the factory and wet parchment to the drying grounds. Grass mowers, rakes, and binder equipment would also save labour, and transport vehicles will be required to move the crop for export.

The chief use for mechanical equipment on the larger coffee estates is in the pulpery and factory and in the handling of bagged coffee. There are mechanical elevators for lifting wet parchment coffee from a draining platform for delivery to transport for carriage to the drying ground, and elevators for bulked and dried parchment coffee to lift it into a hopper for filling bags, or for gravity feed into curing machinery. Such equipment saves many man-hours.

World Economy

A COMPARISON OF THE BEVERAGES

Even though cocoa may be planted in a number of new regions, the losses and potential losses in the west coast countries of Africa on account of the swollen shoot disease are now so great, that it will be several years before new plantations can supply the world's potential demand. There seems, in fact, every reason to fear that the supply will grow less for a while. When cocoa is short then people tend to turn to coffee. Cocoa is a nutritious drink and coffee is satisfying.

Tea can flood the market, especially when the production of the East Indies, now known as Indonesia, gets back to pre-war level. In those days propaganda was rife and aimed at peoples who did not drink tea to any great extent, such as the Africans in equatorial Africa, who are now consuming increasing quantities of tea. Moreover, it is possible to restrict tea growing to the level of world consumption because tea is grown in allied Asiatic countries where such controls are possible and for their own benefit. In comparison with the amount of tea grown in the East, the production elsewhere is very small. Tea is a stimulant, and also a thirst quencher, for cup after cup may be drunk without discomfort. It is not satisfying, nor is it nutritious except for the milk and sugar that go with it. Among those who drink mainly tea but also take an occasional cup of coffee, many will do without coffee when the cost of it is too high.

Even in normal times in Britain, coffee is looked upon as far more expensive than tea, and there is the bother of brewing it, the heating of the milk, and the use of far more milk and sugar than in tea. All this at a time when household help is not easy to find or afford, and when costs have risen along with pay packets so that no more can be afforded today than before the war.

It does no good to coffee in the long run when prices are high, for even coffee drinkers buy less and husband their supplies. Many people who would otherwise drink coffee turn to tea, or to cheaper essences and powders which contain high percentages of chicory and a poorer quality and lower-priced coffee.

While alcohol supplies stimulants to those who care for it and can afford the price, the masses require nourishing and stimulating beverages that are cheap and non-alcoholic; so that coffee, cocoa and tea have become necessities. Soft drinks are merely thirst quenchers no matter how attractive they are to the eye and taste. They have no warmth and are without stimulant. Tired and thirsty people will often drink water in preference to a sweet or acid soft drink if they cannot get coffee or tea.

As so much coffee is produced in Brazil, it is Brazil that causes the supply to exceed the demand and vice versa. In times of a world surplus Brazil suffers most and consequently needs to exercise some kind of control. The co-operation of the governments of Central and North America in limiting their supplies is usually sought. Immediately control is exercised in South and Central America, all the countries which produce less coffee are helped to maintain their economies without restriction, so that planting can still proceed.

The reason is that the main bulk of the Brazilian crop is hard coffee, of lower quality than elsewhere. When the price falls to the minimum at which Brazil can produce coffee, others can still make coffee pay because they produce milder coffees of higher quality in shorter supply. Higher qualities and special marks will find a market while the great bulk of common coffees stagnate.

EARLY DEVELOPMENT OF THE COFFEE INDUSTRY

To supply Europe with coffee, the planting industry flourished first in the Yemen of Arabia, next in the West Indies, and then in Java and Ceylon until leaf rust disease began to take its toll. Leaf disease was not the original cause of failure, because lack of knowledge and financial difficulties contributed to the decline in yields and planting in general. So many estates did not prove profitable; abandoned fields were allowed to get overgrown and become breeding places for diseases and pests; moreover, we did not have the knowledge then of how to control the pests. Coffee was planted on wrong soils and in wrong environments, and because of ignorance was not given proper treatment. It was therefore predisposed to succumb to a new disease of the virulence and destructiveness exhibited by the leaf rust disease. Despair and lack of confidence resulted, so that Ceylon planters turned their attention to other crops instead. The disease spread to the East Indies and India, and production in general began to decline soon after 1874.

The Dutch turned to other species and planted robusta coffee extensively. Had it not been for the two wars—and the last one in particular—followed by

the political troubles in Indonesia which still persist today, then the robusta coffee industry of Java might have reached considerable proportions. India also turned to planting robusta, and found in the 'Kent's' variety of Arabian coffee one that was resistant to the leaf disease. By this time the people of the United Kingdom had shown their preference for tea, so that both India and Ceylon became large producers of tea.

The French have hitherto not produced large quantities of coffee in their colonies where the crop can be grown, and they have hardly succeeded in satisfying the needs of France, which imports from elsewhere. The French, however, were responsible for taking coffee to the Western Hemisphere, and for the propagation and the original supply of the bourbon variety of Arabian coffee which produces the highest quality coffee in the cup.

Chiefly on account of ignorance of how to plant coffee, and of how to maintain the fertility of the soil, attempts to create industries in some other British colonies had only a temporary success. The Nyasaland coffee industry failed, and so did the first plantings of coffee in Uganda where robusta coffee superseded the Arabian kind. The Jamaican industry struggled on despite fearful soil erosion in the Blue Mountain region, and the Kenya industry passed through perilous times when many lost money, though ultimately it emerged triumphant.

Today, the industries which persisted and passed through the dark days are healthy and progressive, due to experience and modern research. They have learnt to avoid or control the diseases and pests and produce coffee of the highest quality. Among them may be listed India, Uganda, Kenya, Tanganyika Territory and the Belgian Congo. The Central American states are not far behind in their efforts to modernize their industries.

The leaf rust disease did not appear in Nyasaland, and was not a contributory cause of the decline in production. It did, however, appear quite early in Uganda and spread quickly throughout East Africa, although there were isolated areas such as the Southern Province of Tanganyika which did not know the disease until the middle nineteen-thirties.

The blockade of the Continent during the Napoleonic wars and the development of the beet sugar industry in Europe provided the reason for a change-over from large-scale sugar production to coffee growing in Brazil. The industry grew apace in the early nineteenth century until by 1850 Brazil accounted for half the world's production, despite the ignorance of proper methods of cultivation and production which was then universal. At one time Brazil's production was three-quarters of the world's total, though it is now a little more than half.

Brazil had, and still has, enormous tracts of country with a soil eminently suited to Arabian coffee. The climate, too, is generally favourable to the species during the long periods when frosts and droughts do not occur. Leaf rust disease has never been present in Brazil or in Central America and though it may have been inhibited to a certain extent by the temperate climate and the periods of frost in Brazil, the same reason cannot be advanced for its absence in the warmer frost-free regions of Central America.

The industry progressed because of the absence of leaf disease and the abundance of cheap labour, including—until it was abolished—the use of slave labour. All the records tell of the utter neglect of the soil, of how wonderful forests were destroyed and coffee planted in the most primitive fashion. Vast areas of the finest land were eroded and leached of their

By courtesy of the Royal Institute for the Tropics, Amsterdam

Robusta coffee growing as a catch crop under rubber trees in Java. They have been capped very low

PLATE LXXV

fertility until it became the practice to consider that the life of a coffee plantation was no more than about fifteen years, after which the owner found new land and started afresh.

Perhaps it is more difficult to persuade vast numbers of people scattered over immense distances to alter their ways, than it is in smaller and more compact regions. Be that as it may, the fact is that little change has been effected, even today, in the methods of planting, cultivating, harvesting and the preparation of Brazilian coffee.[14] Research and modern teaching was begun much later in Brazil, and progress in extension work has been very slow. Much of the coffee produced is of poor quality; it has a harsh and rank flavour, and is hence known throughout the world as 'Brazilian' or 'hard' coffee. Even the softer coffees shipped from Santos are only of medium quality, and are used with higher-priced mild coffees to reduce the cost of blends.

FLUCTUATION OF PRODUCTION AND PRICES

Ever since the coffee industry of Brazil became such an important factor in the world, there has been a long history of fluctuation in production and price. Except for a very slow and steady rise in demand, accountable to increased populations and similar causes, there has been little fluctuation in consumption; indeed, consumption tends to be a little less during and following a period of high prices.

Though the reasons can be over-simplified, the chief causes of world surpluses for more than fifty years have been (*a*) periods of intensive planting during world shortages and higher prices, and then (*b*) a succession of good years and bumper crops in Brazil. The chief causes of high prices have been: (*c*) shortages caused by bad years in Brazil, i.e., widespread damage by severe frost or drought; and (*d*) depression caused by periods of surplus supplies and low prices, leading to the abandonment of marginal plantations, i.e., those which can only remain profitable when the prices are moderate, causing a shortage due to decreased planting.

The cycles of events appeared to reach their zenith in the nineteen-thirties. Prices were higher in the middle and late nineteen-twenties following the severe frosts of 1918. Planting was thereby encouraged until the peak number of trees in bearing in the São Paulo region was reached about 1934. Corresponding with the coming into bearing of millions of extra trees, there were two or three good crop years in Brazil in succession, leading to the largest supplies of coffee that the world had ever known. Consumption in no way increased correspondingly, so that prices tumbled and remained low until after 1945. The war did nothing to ease the conditions, for soon after 1939 the United States became the sole market for coffee produced in the Western Hemisphere. During the controls exercised in the years 1931–44, over seventy-eight million bags of Brazilian coffee were destroyed, enough to supply total world requirements for three whole years.[14]

The coffee slump occurred during a general depression in world trade, which was marked by very heavy falls in the wholesale prices of most primary products. The drop in the price of Brazilian Santos superior coffee between 1925 and 1930 was as much as 48 per cent, but the exceptionally heavy crops of coffee with the prospects of still heavier ones to come had forced down the price of ordinary grades well before the general world depression set in.

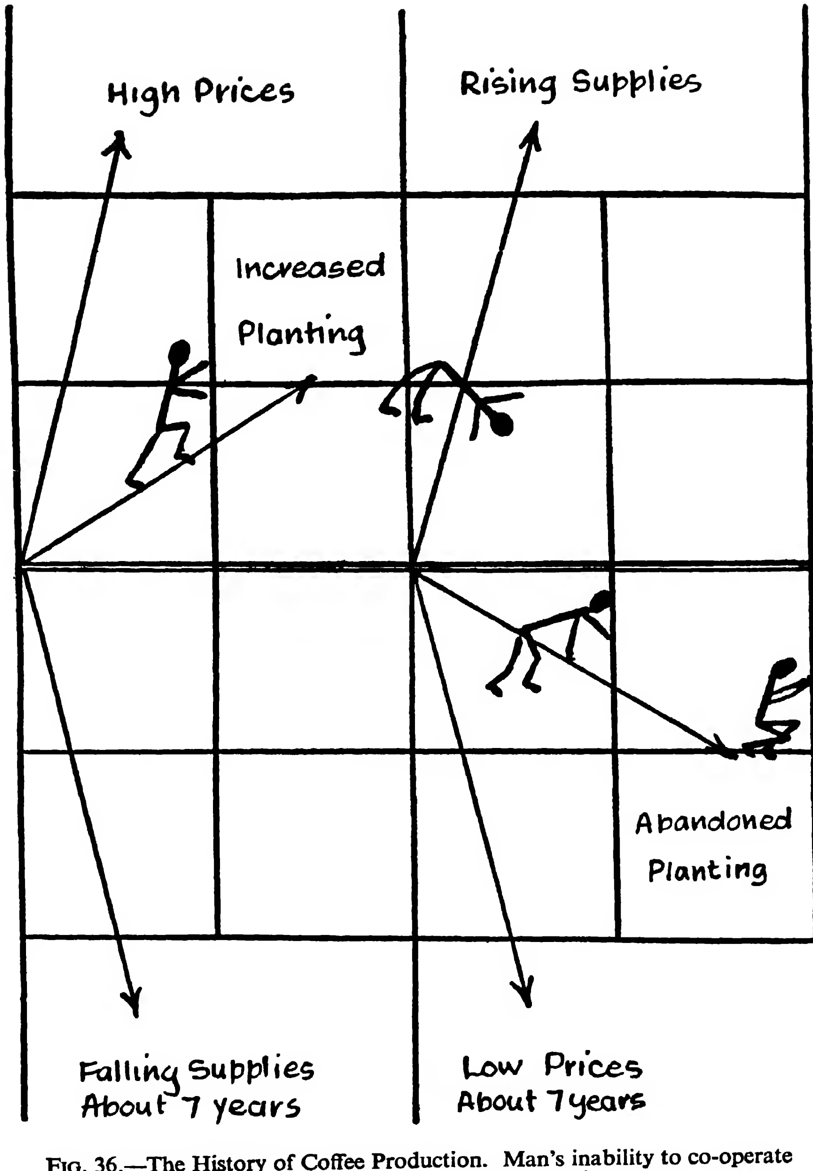

FIG. 36.—The History of Coffee Production. Man's inability to co-operate and stabilize production and prices.

Despite the general and severe slump, the fall in price of the best grades of coffee from Costa Rica and the Empire was relatively less severe.

A fall in prices in 1902, following a bumper harvest in Brazil in the season of 1901–02, led to prohibition of new coffee planting which was maintained for ten years; but after 1912, similar situations were met, not by endeavours to restrict planting, but by the raising of large loans to maintain the price levels by withholding surplus stocks from the market and regulating the flow of coffee to the ports. Loans were floated in 1906, 1917, 1921, and 1927. In each case the immediate object was attained, but these repeated interventions to maintain prices without a control of planting could have only one end. Not only was protection given to old and uneconomic plantations, but a stimulus was given to planting. The disposal of still heavier crops became more difficult to finance.

The Brazilian crop during the 1927–28 season reached the record figure of twenty-six million bags, nearly double that of the previous season, and nearly double the average of the previous five seasons, indicating that considerable areas of new planting had come into bearing under favourable weather conditions. The valorization schemes not only precipitated fresh crises within Brazil but gave an opportunity for increased production in other countries.

EXPORTS OF COFFEE IN THOUSAND BAGS[2]

Countries	*1913*	*1924*	*1928*
Brazil	13,268	14,268	13,881
Colombia	1,023	2,220	2,655
Remainder, S. America ...	1,149	1,053	884
El Salvador	481	815	788
Costa Rica*	217	304	315
Remainder, C. America ...	1,009	949	1,079
Dutch East Indies	435	1,219	1,938
India	167	177	216
British East Africa	34	259	391
Total (including other countries)	19,333	23,041	24,014
Brazilian share per cent ...	68·6	61·7	57·8

*To September 30th.

During the periods of the separate valorization schemes, the exports from Brazilian ports gave no indication of the actual production and of the stocks held back in the country, and it was not until after 1944 when such vast quantities of old stocks had been destroyed that equilibrium was regained. Meanwhile many marginal estates had been given up, thousands of trees had been uprooted and further planting had ceased. In fact production had been brought down more or less to the rate of export. It was then seen that Brazil's production had declined, whereas the production of many other countries, especially of Colombia, El Salvador, and British East Africa had more than doubled the exports which prevailed at the time the first valorization scheme was brought into being.

Brazil's case is rendered more serious by the fact that the increasing production elsewhere is largely composed of higher quality mild coffee. Brazil's

market is chiefly found in the United States, but American consumers are beginning to require and to have a liking for higher quality coffees. The American trade is beginning to show concern that it has such little control over the production side of an industry on which they largely depend for their supplies, whereas considerable control is exercised in regard to the British colonial production.

Should there be further slumps in future, there will be far more higher quality mild coffee available to satisfy a more choosy demand. This would affect not only Brazil, but producers of coffees everywhere in regard to their lower grades.

Time is against Brazil, for she is slow in responding to improved techniques. Her coffee is of the Arabian species. She has only to turn to careful picking, to the wet process of preparation and to proper drying to make all her coffee equal in quality to the best produced elsewhere. Even her softer, medium quality coffees could be raised in quality to safeguard her future, though the trade in the west would then find it increasingly difficult to secure enough medium quality coffee to mix with high quality for cheapening blends. Unless Brazil reorganizes her industry and raises the quality of her coffee, a further decline may be expected in the next half-century and she may well lose her lead in the coffee world.

AN UNSTEADY EQUILIBRIUM

The new state of equilibrium existed on tenterhooks for the years immediately following 1945. Supply available for export had been brought about equal to the demand, and it was hoped that bad years might even up good years and that a severe lesson had been learned. For several years since then the world coffee production has been about twelve per cent below the pre-war average, when the output exceeded the demand and stocks were still considerable. Today Brazil is producing less, Colombia has improved her output; Indonesia has some way to go before pre-war production is achieved, but African countries have advanced rapidly, and many smaller regions contribute increasing supplies of coffee to the world's pool.

An uneasy equilibrium is subject to scares, and widening price fluctuations, but nobody appeared to anticipate the result of a poor forecast for the 1949–1950 Brazilian crop. What had happened to the billion extra trees which had been planted and had come into bearing during the early nineteen-thirties? There was more reason to fear a further slow accumulation of stocks following a period of better prices and a later fall in price, though equilibrium had for the moment been obtained.

It is difficult to appreciate and explain the reasons why the price of coffee should have risen so steeply in 1949. The war stimulated consumption in the west, and stocks were greatly depreciated in Europe. Recovery permitted Germany to buy again, and other European countries, which had been starving for coffee, came into the market as their wounds healed. On the other hand, several countries which depended on coffee production for their financial stability had been badly hit during the depression, and had been forced to diversify their industries. The cost of living rose so that wages had to rise in an ever-winding spiral, causing agricultural workers who were poorly paid to move to the towns and learn other trades. So many moved towards the towns in Brazil and took employment elsewhere that labour in the coffee fields

became scarcer—a state of affairs which might persist and curb the trend towards overplanting in future.

All the varying influences appeared to have a cumulative effect and to affect the situation at the same time, so that prices rose and have continued high since 1950, boosted to even greater heights and a level never known before by severe frosts which occurred in Brazil in 1953 with disastrous effects on the coffee fields. The price for the best quality Arabian coffee at Nairobi auctions, in Kenya Colony, reached £800 and even £1,000 per ton, and then slowly steadied to between £500 and £600 per ton. Even robusta coffee sold for more than £500 per ton during this period. Compare these prices with £77 per ton for Kenya, and £37 per ton for Uganda estate robusta in the year 1930.

For more than five years prices were phenomenally high, bringing fortunes to those with a few hundred acres of productive coffee. Such prices might well be calamitous in the long run for they were more than human nature could withstand. Figures are not available regarding the new planting which began to take place throughout the coffee-growing world. No country has attempted as yet to restrict planting, so that history appears to have repeated itself on a grand scale. In British Commonwealth and Colonial territories many have planted every piece of suitable land that can be spared. Native peoples have been urged to plant coffee, and helped to the extent of supplying them with nursery-grown and selected stock at no more than ½d. per plant.

All the British effort, however, must be but a drop in the ocean to compare with what must have taken place in Central and South American countries and in Brazil. Brazil appears to have forgotten the lessons of the past in her anxiety concerning the fever of planting in neighbouring countries of the Western Hemisphere. She began similarly to plant more coffee on a considerable scale, meaning, perhaps, to flood the market, endangering her own security and her leading position in the coffee world.

In Brazil the people have grown to expect their government to protect them when surpluses and difficulties arise. Their attitude is somewhat that of the fatalist. When prices are high their profits are sufficient and they see no reason to go to the expense and trouble of modernizing their methods or producing better quality. On the other hand, when prices are low they feel it is then not worth their while. Hence very little is accomplished.

The modern towns in Brazil, surrounded by industrial achievement, are a kind of façade to the primitive development of the surrounding country where transport is lacking, good roads are few, and agricultural practices have not altered much during the last hundred years. The agricultural folk are a simple, likeable people who are inclined to follow local opinions. When the more important among them start planting more coffee then the rest follow, and during the bad years they all start abandoning coffee in favour of cotton or cereals planted between the coffee rows.

With the rising cost of wages and of living it is becoming more expensive to plant and cultivate coffee in Brazil, so that the lower limits at which coffee can be sold at a profit are constantly rising.

With rising costs it is becoming more difficult to regenerate the older land that became infertile and was abandoned years ago. New plantings tend to take place on land in new regions where transport facilities have yet to be developed. These facts together create doubt as to whether, despite a long

period of high prices, and new planting, Brazil can create a vastly increased production for some while.

The war prevented the movement of coffee from the West to Europe, and then hard currency exchange rates hindered a resumption of trading between Europe and the West. We could no longer afford the high-priced coffees of Costa Rica and other American countries. Our own economy in matters concerning coffee became more closely tied to our colonial production, which automatically received preference. Our coffee-producing colonies would be in a sounder position to meet expected troubles of the future if our own consumption of coffee was greater than it is.

WORLD CONSUMPTION[14]

Years	*Average world total in thousand bags of 60 kg.*	*Percentage of world total*		
		U.S.A.	*Europe*	*Other countries*
1909–13 ...	17,554	38·9	54.6	6·5
1935–39 ...	27,625	50·2	41·5	8·3
1940–44 ...	22,660	75·6	12·2	12·2
1945–49 ...	30,077	68·6	20·6	10·8

The table shows how world consumption has been increasing over the years, though hindered by World War II. During the war it is seen how America came to the rescue and stepped up her consumption while that of Europe fell. It will also be noticed that Europe was recovering during the period ending 1949, but still had a lot of leeway to make up.

CHANGES IN CONSUMPTION PER HEAD IN VARIOUS COUNTRIES[14]

Country	*Average*			*1948*	*1949*
	1935–39	*1940–44*	*1945–49*		
Norway	14·1	1·9	9·7	12·1	11·3
Sweden	17·6	6·6	12·5	11·1	11·0
Finland	13·7	2·5	3·4	5·4	6·2
Denmark	18·0	1·0	6·2	6·5	8·4
Holland	9·5	0·8	4·0	4·8	5·3
Belgium and Luxembourg ...	12·9	1·5	18·0	21·3	22·4
France	9·7	2·5	3·8	3·8	4·7
Switzerland	9·1	5·1	8·9	12·1	8·7
Germany, Austria ...	4·9	0·3	—	·5	1·1
Canada	3·6	5·1	6·0	6·8	7·4
South Africa	3·4	5·0	4·8	4·5	4·1
Italy	1·7	0·2	1·3	2·0	2·3
U S.A.	14·0	15·8	18·6	18·6	19·3
United Kingdom	0·8	1·5	2·0	2·3	2·0

Several interesting conclusions may be drawn from the table showing the consumption per head. The individual use of coffee by the Scandinavian peoples seems to have become less since the war. Belgium on the other hand has almost doubled her consumption, though some of this coffee may have gone to France, or to the occupying forces in Germany. Switzerland was largely unaffected by the war and her *per capita* consumption remained fairly static. Canada appears to have increased consumption steadily throughout the war years along with America, but the increase in the United Kingdom is accounted for by the rationing of tea.

Should prices fall considerably then consumption in Europe is bound to respond favourably so that the first wave of an increased production might be absorbed. Prices might then hover for a while on the brink of a steep decline.

SLUMP TACTICS

What are the safeguards to bear in mind concerning the possibility of falling prices in future? What should we do to become resilient and thus ride the tide of another depression?

Diversity of production is one means, and happily enough most of our own coffee-growing countries do not depend on coffee alone. It is the individual who might suffer—he who goes in for planting coffee alone, and has no plans ready-made for growing an alternative crop.

Now is the time, when prices are high, to build up financial strength, to re-equip and invest in every possible labour-saving device and quality-raising procedure. Stabilizing funds have been wisely built up in Uganda, and all peasant coffee industries elsewhere should be brought into co-operation, warned of the future and guided to put by for a rainy day. Our settler coffee producers of East Africa have progressed a long way towards co-operative enterprise, but they could go farther still towards making their industry secure.

Again we are happily situated in having inaugurated research, with many of the problems already solved. We can bear with diseases and pests and produce more to the acre than is procurable in the West. We have the ability to carry forward the selection of high-yielding strains so that the greater yield per acre per annum will go far to even up losses. We aim at producing the highest quality Arabian coffee except in the few areas where robusta coffee is being grown.

Large-scale robusta coffee growing is most unwise in view of the world trends today. One has only to remember the low prices for robusta coffees during the early nineteen-thirties—£28 and £37 per ton against Brazilian Rio No. 7 at £40 per ton. If Brazil had not destroyed those 75 million bags what then would have been the position? Where will the outlet be if history repeats itself as it has every indication of doing?

Knowing that phenomenal prices over the last few years have caused planting programmes to be stepped up throughout the world, it is surely wise to rediscover the reports of the Imperial Economic Committees, published in 1931.[1] They pointed out that the percentage falls in price during the slump had been less severe in regard to the higher quality mild coffees than those for the poorer qualities. While the prices of coffees of all origins over a period of years tended to move in general sympathy, the effect of a slump in Brazilian

prices was more directly felt by the coarser varieties of 'mild' coffees such as the robustas, which were nearer to the Brazilian in price level.

This, they said, 'is of first importance when coffee producers within the Commonwealth have to consider the effect on their industries of a fall in price. All grades would be affected, but the better grades would suffer less because they supply a demand which is distinct from that for Brazilian coffees. The difference in flavour between the two types is so marked as to form a difference in kind rather than degree, and, in the opinion of competent judges, those markets which are buyers of mild coffees would continue to buy them no matter how low the price of Brazilian coffee fell, while the influence of Brazilian prices would be indirect rather than direct.'

But supposing during a future depression the supply of the better mild coffees was found to have increased very considerably, especially in the South and Central American countries? Fortunately the demand for mild coffees has steadily expanded since the last slump. In any case the lower grades of mild coffees might be brought down to an unprofitable price level, even if they succeeded in finding a market.

Pre-war, the London market had far more strength than it has today. The war divorced much of the re-export trade from London. Bulk buying by the Ministry of Food brought Coffee Boards into being in most of our coffee-producing countries, so that sampling, marketing, bulking and shipment were arranged locally. As agreements with the Ministry of Food came to an end, first a proportion, and then more of the crops in the separate countries were voluntarily sold at local auctions, so that these local markets became new factors, and much of the coffee is now shipped and sold to various countries direct. London is thus short-circuited in many of the deals. What effect this might have during another slump remains to be seen.

During a prolonged slump it is the man who can hold on to his coffee acreage by having other interests, who will gain in the long run when the pendulum swings in the opposite direction. This is always provided he is producing high quality coffee on a healthy, well-managed estate. He can restrict his own production by sacrificing all but the best grades of coffee produced by his trees, and by reducing crop to benefit their health and stamina. To uproot coffee and shade trees is as expensive as keeping his coffee on a maintenance level, and it is wise to remember that the yields of older trees in good health are double those of newly-planted trees when better prices return. The greater the push given by over-production to the swing of the historical pendulum, the wider the swing should be in the opposite direction but the slower it takes to swing to and fro. (*See* following table.)

In the matter of grading, pre-war East African producers were said to be at a disadvantage, especially in regard to the re-export trade, because of the small size and the scattered nature of the estates. Few of them reached a size of 500 acres. Estates in Guatemala are often of 1,000 and 2,000 acres, and though estates in Costa Rica and other Central American countries are not, perhaps, as big, they receive large quantities of cherry coffee from neighbouring smallholders. These sell their coffee, so that the central 'Beneficiador' sells it under his own mark.[1]

The large amounts of cherry supplying central factories facilitate the employment of more elaborate methods and machinery, and the extraction of more grades. In Costa Rica coffee was gravity-graded in washing channels long before this was done in East Africa, and many of the estate factories

PRICES IN SHILLINGS PER CWT.

1925 – 1930

	Average Price 1930	Decrease in shillings per cwt.		Decrease per cwt.	
		1930 on 1925	1930 on 1929	1930 on 1925	1930 on 1929
	s d				
Costa Rica	115 0	46	24	28	17
India	86 0	54	41	38	32
Tanganyika	77 9	47	38	37	34
Kenya	77 6	54	38	41	33
Uganda Arabian	63 6	54	35	43	36
Brazil.					
Santos Superior	56 4	53	40	48	42
Rio No. 7	40 0(*a*)	54	33	43	45
Robusta.					
Uganda estate	37 0	29(*b*)	45(*b*)	44(*b*)	55(*b*)
Bukoba native (*c*)	28 0	58	32	67	53

(*a*) New York Spot.
(*b*) 1930 on 1927.
(*c*) Bukoba prices ruling at the end of the year.

are run by water power. The factory methods there were considerably in advance of our own, and though our own are now equal, we still have not got the same quantities to deal with.

The Costa Rica method of dealing with coffee from a widespread area at a central factory, had, and still has, an important bearing on quality and the price it obtains in the world's markets. The London market was always interested in large parcels of uniform coffee of good quality, and this it found in Costa Rican shipments in those earlier days. The report of the Economic Committee went so far as to say that it would be of benefit to the East African industry if co-operative preparation and curing could bring about standard grades I, II and III. Buyers would then be able to buy their 500 or 1,000 bags of a particular grade to meet a foreign order, and be in a position to certify that they were all of the same standard.

In Brazil there are numerous classifications and grades of coffee. A No. 1 Grade is not found because it implies perfection. The best grade procurable is a No. 2 which allows for four imperfections in two-thirds of 1 lb. The poorer grades are progressive in the number of imperfections allowed, e.g., No. 5 Grade has forty-six, and is the average grade of coffee produced in São Paulo. Imperfections are counted against black beans, since a defect, i.e., a black bean, counts as equal to five broken beans, two light beans, three parchment shells, one berry husk or one stone of bean size. No. 5 Grade may therefore have forty-six black beans or forty-six small stones in two-thirds of 1 lb., or in one and a half kilo. of coffee.

The robusta coffees of Uganda and Tanganyika are government-graded on

somewhat similar lines, depending on the number of imperfections within the coffee. The author always thought that there should have been a first grade without any imperfections at all, and he sees no reason to alter his opinions now. It is to our ultimate advantage to up-grade coffee to the uttermost limits in order that it should be sought after and well known for quality, especially when it is produced and sold in bulk.

QUALITIES OF THE WORLD'S COFFEES

Most of the coffee in Colombia, Venezuela, Guatemala, El Salvador, Costa Rica and Mexico is derived from the bourbon variety of Arabian coffee, a variety known to produce bold and plump bean when it is well-grown in an environment where the rainfall is sufficient. It is also a variety renowned for its high liquoring qualities. Hence a varietal difference and the method of preparation give the reasons why coffees from these countries are known as high-grade milds. It is in these countries that the recent high prices have been most effective, and, of course, large-scale new planting is taking place, hindered only by politics.

Brazil has taken to planting bourbon coffee for some years, rather than the older 'nacional' var. *arabica*, especially in the areas renowned for the softer coffees. The methods of harvesting, preparation and grading are the stumbling blocks to quality on a higher scale and only a very small proportion of the Brazilian crop produced by the wet method, can be rated as high-quality mild coffee.

Blue Mountain Jamaican coffee has been developed as a strain, and doubtless much of the excellence of quality depends on the local soils and climate. It exhibits smaller differences when planted in Kenya and the quality of the Kenyan 'Blue Mountain' does not compare with that from Jamaica itself.

Much of the East African coffee was developed from bourbon seed, but there is now a mixture of other strains of which the 'Kent's' coffee is beginning to predominate. The bourbon coffee proved susceptible to disease and did not seem to have the stamina to put up with shortages of rainfall. The liquoring qualities of 'Kent's' coffee are as good as bourbon, but though a large proportion of the East African coffee is of the highest quality, it suffers in bean size and plumpness, on account of climate and in variability.

Indian coffees are largely consumed within the country, and the exportable surpluses of Arabian coffee of good mild quality compare with East African grades, though they differ slightly in liquor and acidity.

STORAGE OF COFFEE

Coffee is produced in countries having humid atmospheres, so that storage for any length of time is very difficult without a severe loss of quality. In dry air, even though the temperatures may be high, raw coffee can be stored for a number of years without any real deterioration. It is easier for the middleman in a temperate consuming country to store raw coffee than it is for the coffee producer or his government in the country of origin, unless storage is provided in the drier regions of a continent adjacent to coffee-growing areas. Prolonged storage affects colour and flavour.

More especially is high quality coffee affected. For a while, the harsher-

flavoured and poorer-quality coffees may be mellowed and slightly improved. Stored coffee may obtain an 'old-crop' flavour because of a continued deterioration, but coffee may be taken into special storage and aged to develop qualities superior to that from the latest crop and thus obtain a better price. Much depends on the type of coffee and the conditioning process. The milder coffees tend to lose 'bite' during a mellowing or ageing in storage, but the harsher coffees may so lose their rank flavour that they may be used in greater quantity in blends. Deliberate ageing appears to be a practice that is dying out as softer coffees and 'milds' become available in greater quantity.

World surpluses of coffee have been known to arise with the suddenness of world shortages, and it might be found in some countries that storage is inadequate or badly sited from the point of view of humidity and availability. Where countries are among the minor producers it may well be found that storage is necessary while stabilization funds are being used and restrictive schemes are being brought into operation. Co-operatives and governments who know that a feverish planting campaign is in full progress, should take time by the forelock and arrange to provide storage of the right kind in good time before overproduction is proved.

Since most countries are progressive in regard to food production, extra storage will always be an asset, especially among peoples who depend chiefly upon grain crops where drought and famines are likely to occur. All the East African countries, for instance, have dry areas within reach of the humid coffee-producing regions, and grain storage problems in times of surplus.

Variability in coffee production once depended on the size of the crop more than it does now. A bad year in Brazil was balanced by a good following year, or vice versa. During recent years we have entered a new phase—that of extensive planting during periods of better prices followed by overproduction, disappointment, individual ruin, abandonment of plantations and deliberate uprooting. It is an evil phase, a kind of vast carrier wave on the back of which are carried the shorter waves of good and bad seasons. When production is rising the bad years have little effect but the good seasons topple the scale towards disaster.

INTERNATIONAL AGREEMENT

When disaster ensues international agreements are sought too late, albeit they are seemingly impossible at other times, at least between the West and the Middle and Far East. Agreement among the countries of the Western Hemisphere, though often attempted, has been found difficult to achieve, and it was only by the imposition of import quotas by the consuming country of America that agreement was reached for a period covering the war years, when America became the only market in that part of the world.

The United States are naturally apprehensive concerning the financial stability of the Central and South American countries who so largely depend upon coffee both directly and indirectly for their revenues and well-being. In times of depression and near disaster it is indeed within America's province to extend advice, and within her organizing ability to bring about concerted action. It is not easy, however, for a country consuming coffee on such a large scale to halt a price slide which would give her countrymen cheaper coffee.

The vested interests in the coffee wholesale and retailing trades are too great, and there are many references to their distrust of the estimates of crop size, the reasons for high prices, and attempts to rig the market by producing countries in the past.

As regards the Middle and Far East, the separate productions in the various countries are in themselves so small by comparison that agreements to restrict production could have little effect and would not seem worth while. Moreover, except for robustas which are virtually priced off the market in times of slump, the coffees produced are of a kind which supply special needs. From a high-level point of view it would be better to permit the natural influences of supply and demand to control the separate planting industries, rather than to interfere by overhead international agreements with the giants of the coffee trade to the West.

The most flourishing production of coffee other than in the Western Hemisphere is found in East Africa and the following statistics define the position there.[4]

EXPORTS OF KENYA COFFEE IN CWT.

1950/51	*1951/52*	*1952/53*
228,205	352,129	264,166

DESTINATION IN CWT.

	1950/51	*1951/52*	*1952/53*
United Kingdom ...	87,942	86,475	103,495
South Africa	10,848	22,171	13,144
Australia	5,015	3,734	10,215
Canada	32,955	27,526	5,593
United States ...	18,114	23,221	2,938
Germany	24,711	51,620	93,269

PRICES PER TON

	1950/51	*1951/52*	*1952/53*
Average price ...	£521	£484	£470
Highest price ...	£648	£603	£518

Despite a continuation of high prices, increased planting, and the encouragement of a native industry, it is unlikely that production in Kenya will reach much more than 25,000 tons or half a million cwt. of green coffee per annum within the next decade.

PRODUCTION IN TANGANYIKA
IN TONS

Year	*Arabian coffee*				*Robusta coffee*
	Estate grown N. Province	*Native grown N. Province*	*Bukoba production (a)*	*Total*	*Native Bukoba*
1949	2,246	4,225	2,087	8,558	5,200
1950	1,619	5,455	1,625	8,699	6,420
1951	2,122	4,890	2,134	9,146	6,650
1952	2,582	5,987	1,870	10,439	7,837
1953 estimate ...	1,480	5,500	1,070	8,050(*b*)	6,933

(*a*) Mostly native but includes a little estate production.
(*b*) 1953 figures have been exceeded by a few hundred tons.

PRICES PER TON

	1953	
	Approx. average	*Highest*
Native Arabian ...	£536	£686
Estate Arabian ...	£561	£688

Coffee land is limited in Tanganyika and even if the industry received maximum encouragement it is unlikely that production would rise to more than 15,000 tons of Arabian coffee and 10,000 tons of robusta coffee within the next decade.

PRODUCTION IN UGANDA
IN TONS

	1948/49	*1949/50*	*1950/51*	*1951/52*
Native robusta ...	22,938	23,185	30,931	32,305
Estate robusta (*a*) ...	4,000	4,000	4,000	4,000
Total	26,938	27,185	34,931	36,305
Native Arabian (*b*) ...	2,370	2,370	2,370	2,370

(*a*) Average production only.
(*b*) Average production clean coffee calculated at 80 per cent of weight of parchment.

PRICES PER TON

	1949/50	1950/51	1951/52
Native robusta ... ... Price range per ton.	£ 170/330	£ 280/350	£ 350/370

The 1952–53 native robusta crop yielded 25,520 tons of which 18,151 tons were rated F.A.Q. fetching on the average £350 per ton, and 6,790 tons U.G. (undergrade) priced on the average at £310 per ton.

New plantings have been made on a considerable scale but it is not thought that production could rise to a figure above 90,000 tons of robusta and 4,000 tons of Arabian coffee within the next decade.

TOTAL PRODUCTION IN EAST AFRICA
1952/53

Country	*Arabian*		*Robusta*	
	Present	*Estimated maximum in foreseeable future*	*Present*	*Estimated maximum in foreseeable future*
Kenya	15,000	25,000	—	—
Tanganyika ...	10,000	15,000	7,000	10,000
Uganda	2,500	6,000	25,000	90,000
Total tons	27,500	46,000	32,000	100,000
Total cwt.	550,000	920,000	640,000	2,000,000

The figures would be entirely altered by a severe fall in prices during the next eight years. The estimates are the author's, based on his knowledge of East African affairs, in a desire to show that even with an all-out effort, influenced by the present high prices, it is unlikely that production would be doubled in the next ten years.

RECENT HISTORY AND STATISTICS

The Ministry of Food became the sole buyer of coffee for the United Kingdom early in 1942, and bought all the exportable supplies from East Africa, the West Coast and Jamaica. The purchase price was adjusted from year to year in fairness to the producers, while the maximum retail price in the United Kingdom was fixed at 2s. 8d. per lb. The distribution was left to the coffee trade and rationing was never introduced. In 1947 five-year contracts were made with British East Africa and continued for a further two years in 1952. It was agreed that part of the purchase from Tanganyika and Jamaica after 1949 and from Kenya after 1950 should be sold in hard currency countries. Then, in August 1951, the importation of the domestic requirements of the United Kingdom not covered by these contracts was freed to the trade, and coffee auctions began again in London in January 1953.

The increase in the cost of supplies imported by the Ministry meant that the maximum retail prices had to be raised in April 1947 to 2s. 10d. per lb., in May 1950 to 3s. 4d., and in May 1952 to 5s. 4d. per lb. Prices were decontrolled in August 1952 and they then began to rise again. The consumption *per capita* which had risen to a high of 2·3 lb. in 1948 has fallen since to less than the pre-war figure of 0·8 lb. per head.[3] Meanwhile, on account of high prices, consumption had fallen in the U.S.A. from 19·3 lb. per head to about 16 lb., proof that high prices deter increased consumption. The derationing of tea may have helped to decrease the U.K. consumption, and though tea prices have risen they are a lot cheaper than coffee.

Coffee has been especially important to Brazil and Central American countries because high prices were maintained while those for other commodities were falling. This has been fortunate for countries like Colombia, El Salvador and Guatemala who rely on coffee for more than half their exports. Because currency difficulties reduced the volume of trade in other commodities, the coffee exports from Brazil in 1952 are recorded at as much as 74 per cent of the total exports, to compare with 60 per cent in the three preceding years and 45 per cent in 1938.[3]

Measures to maintain the price of the country's main export by the fixation of minimum prices and of monthly quotas of dispatches were followed at the end of 1952 by the setting up of the Brazilian Coffee Institute on lines similar to the former National Coffee Department, in order to maintain adequate prices to growers, if necessary by the purchase of excess supplies. Then came the frost of 1953 and a severe reduction in crop. Brazil does not appear to have learnt a lesson from the past, for the emphasis is still on crop production at any price rather than the modernization of procedure, the raising of quality and the reclamation of older abandoned areas. It is stated that even with an increase of one million acres under coffee since the end of the war, the total in 1952 was still 7 per cent less than in 1939.

In Colombia small holdings account for a large part of the total area under coffee which was estimated in 1949 at 1,621,000 acres. The production in 1952 reached a record figure of 7·9 million cwt. reversing the downward trend of the two previous years. Other Central American countries have also extended their plantings. Venezuela showed a marked recovery during 1951 and 1952, while the production of El Salvador, Guatemala and Mexico has been at a high level. The increase in exports from Mexico in 1952 was striking, at least 50 per cent greater than pre-war, and those from Guatemala and the Dominican Republic reached record figures in the same year.

Africa as a whole today accounts for about 15 per cent of world production compared with 8 per cent before the war. The increase in French West Africa is said to be more pronounced than in Uganda or Angola. Planting in all three countries is increasing all the while.

The expansion of the coffee industry in India by 1952 was 30 per cent greater than pre-war, though the coffee is used mainly for local consumption. Cuba prohibited exports for a while because she needed all her coffee for internal use.

ESTIMATED PRODUCTION AND EXPORTS 1952
IN THOUSAND TONS[3]

	Production					Exports				
	Average 1937–39	*1949*	*1950*	*1951*	*1952*	*Average 1937–39*	*1949*	*1950*	*1951*	*1952*
Total ...	(a) 2,217	(a) 1,995	(a) 2,015	(a) 2,010	(a) 2,215	1,632	1,974	1,690	1,836	1,857
Commonwealth	64	66	76	90	93	57	47	63	73	79

(*a*) Partly Estimated.

It is shown that world production in 1952 was back to the pre-war level and might have exceeded it in 1953 if it had not been for the frost in Brazil. The figures show the steady increase exhibited by Commonwealth production.

COFFEE IMPORTS INTO THE UNITED KINGDOM
IN 1,000 CWT.[3]

	Average 1937–39	*1949*	*1950*	*1951*	*1952*
Total	454	880	798	851	851
From Commonwealth ...	226	441	388	450	454

AVERAGE DECLARED VALUE OF UNITED KINGDOM IMPORT IN PENCE PER LB.

1937	7·36
1938	7·46
1939	7·02
1946	10·57
1947	13·68
1948	12·28
1949	13·68
1950	29·45
1951	34·84
1952	35·41

Since 1949 the United Kingdom has drawn her supplies from Brazil instead of Costa Rica. This would appear to show a deteriorating appreciation of good coffee. In fact, much of the robusta and poorer quality coffees imported nowadays into the U.K. is used with chicory for the making of coffee powders and essences to which the public are beginning to become addicted.

AREA UNDER COFFEE IN SOME OF THE PRODUCING COUNTRIES. (In thousand acres)[a]

Country	*1937*	*1938*	*1939*	*1946*	*1947*	*1948*	*1949*	*1950*	*1951*	*1952*
Brazil ...	8,549	8,630	7,517	5,946	5,967	6,089	6,271	6,581	6,766	6,976
El Salvador ...	269	—	216	249	255	319	—	261	—	245
Mexico ...	295	302	295	334	335	335	358	408	411	432
Guatemala ...	277	295	278	—	—	—	—	364	—	—
Costa Rica	—	—	—	—	118	—	—	121	129	125
Indonesia (*a*) ...	265	256	245	—	—	80	87	111	116	110
Madagascar ...	232	—	—	247	—	157	179	256	250	283
Belgian Congo(*b*)	149	172	180	160	167	168	166	175	168	184
French W. Africa	173	210	247	445	469	455	455	515	588	568
Angola (*c*) ...	—	—	—	292	303	302	312	313	324	—
India (*d*) ...	190	182	181	211	217	219	221	225	229	235
Tanganyika ...	118	125	125	100	95	97	104	105	106	108
Kenya ...	105	94	89	76	64	64	60	60	60	61
Uganda ...	64	66	71	170	180	181	186	201	224	252

(*a*) Planted area on estates only; in 1948 those in Federal Territory only.
(*b*) Harvested area only, including Ruanda-Urundi. Part estimated.
(*c*) European cultivated only. Africa cultivated estimated 1951 at 64,000 acres.
(*d*) At partition. All in Indian Union.

EXPORTS OF RAW COFFEE FROM PRINCIPAL PRODUCING COUNTRIES. IN THOUSAND CWT.[4]

	1937	*1938*	*1939*	*1946*	*1947*	*1948*	*1949*	*1950*	*1951*	*1952*
Brazil ...	14,317	20,211	19,485	18,312	17,515	20,659	22,875	17,521	19,319	18,685
Colombia ...	4,876	4,994	4,372	6,687	6,306	6,599	6,389	5,292	5,662	5,943
El Salvador ...	1,331	1,059	1,098	948	1,232	1,186	1,468	1,365	1,297	1,317
Guatemala ...	927	965	864	979	1,099	955	1,079	1,081	985	1,199
Venezuela ...	821	706	539	797	606	706	434	367	370	597
Mexico ...	690	691	690	656	647	619	965	905	1,014	1,029
Costa Rica (*a*)	461	431	350	305	356	457	329	392	329	349
Haiti (*a*) ...	488	493	576	478	485	447	548	517	500	616
Nicaragua	311	281	343	232	198	285	135	413	317	372
Ecuador ...	277	270	254	150	205	384	204	399	327	393
Dominican Rep.	217	166	278	205	180	227	283	253	280	517
Cuba ...	131	134	168	—	—	—	—	—	—	—
Angola ...	369	373	408	915	866	1,051	913	740	1,268	938
French W. Africa	205	285	366	717	867	1,017	1,255	1,137	1,238	1,405
Belgian Congo(*b*)	358	443	474	385	479	601	619	657	697	603
Ethiopia ...	256	237	67	298	308	302	440	368	597	425
Uganda ...	258	280	343	628	421	756	478 (*c*)	639	873	789
Tanganyika ...	272	275	332	200	277	225	241 (*c*)	307	336	379
Kenya ...	274	342	338	192	212	286	156 (*c*)	205	199	338
Madagascar ...	418	811	609	440	577	393	504	883	599	823
Jamaica ...	68	84	75	20	27	25	24	27	22	22
India ...	128	140	222	85	63	1	40	75	21	42
Indonesia ...	1,937	1,345	1,287	31	7	47	102	267	465	362
Total ...	29,390	35,016	33,538	33,660	32,933	37,228	39,481	33,810	36,715	37,143

(*a*) Years ending 30th September in the year shown.
(*b*) Including coffee from Ruanda Urundi.
(*c*) Excluding trade between Uganda, Tanganyika and Kenya which, in 1952, totalled 7,000 cwt.

AVERAGE ANNUAL PRICE OF RAW COFFEE ON THE NEW YORK SPOT MARKET (U.S.A. cents per lb.)[3]

Year	Brazil		Colombia		Venezuela Tachira washed(a)	Costa Rica High ground(b)	El Salvador washed (c)	Guatemala Best washed(d)	Mexico Coatepec washed	Dominican Republic Good washed	Haiti Good washed
	Santos	Rio	Medellin	Manizales							
1937 ...	11·04	8·70	12·19	11·60	10·96	12·72	11·20	11·10	12·08	10·57	10 25
1938 ...	7·66	4·85	11·51	10·97	10·63	11·00	9·51	9·38	11·47	8·68	8·24
1939 ...	7·38	5·09	12·27	11·60	11·87	10·13	9·22	9·45	11·75	7·98	8·84
1946 ...	18·31	13·32	21·40	21·00	20·71	21·18	20·61	20·45	21·67	18·70	18·68
1947 ...	26·72	13·56	30·67	30·11	29·56	30·37	29·86	28·59	30·37	26·85	26·70
1948 ...	27·06	14·33	33·01	32·54	31·42	32·46	32·17	30·58	32·28	28·12	28·25
1949 ...	31·76	21·59	37·66	37·41	36·76	37·49	36·76	34·88	36·94	32·18	32·42
1950 ...	50·52	37·62	53·48	53·25	52·73	53·67	52·98	51·37	52·60	49·85	50·13
1951 ...	54·20	45·65	58·87	58·74	58·02	55·00	57·71	55·35	57·34	54·23	54·70
1952 ...	54·04	48·86	57·08	57·01	56·13	57·25	56·42	54·83	56·15	53·19	53·99

PROMOTING DEMAND

The only way that the consumption of coffee could be increased in the United Kingdom would be by all-out propaganda, and by using the methods of packaging adopted by the trade in the United States. It would be necessary to throw aside the quibble regarding the brewing of coffee from freshly-roasted and freshly-ground berries, because the troublesome compliance with such advice deters the use of good coffee. Rather should there be propaganda to the effect that ground and roasted coffee in a sealed tin is good enough for an epicure.

The production of something ready to use in a tin is of great persuasion to the housewife. Though such advice may horrify the minority who insist on superfine coffee, those who like to brew their coffee from freshly-roasted and ground berry could always have it so, whereas a new approach to pure coffee in the tin would offer the public much better coffee, and lead to a better appreciation of moderately good coffee than they have at the present time. It might wean them from the use of essences and concoctions which contain large percentages of chicory. The United States packaged coffee contains very little—if any—chicory at all.

It would be necessary for Commonwealth coffee producers through their Coffee Boards and Associations to promote demand; indeed, to arrange for the blending, roasting, grinding, and packaging of Commonwealth coffees in brands and prices to meet all tastes and all purses, as is done in the United States. Brands permitting moderately good coffee to be bought at reduced prices can be arranged by blending lower-priced grades of 'milds' and triage along with robusta as a filler, provided it is expertly roasted and sold ground in sealed tins.

At the time of writing there is no serious attempt to promote consumption in the United Kingdom, as such is understood in the States, and nothing to compare with the organization which assists tea growers. It seems foolish to increase production within the Commonwealth without devoting research and attention to promoting the consumption in our own country and in neighbouring Europe. There are no signs that the adjustments of pre-war years will endure.

In face of the failure to reach any kind of international agreement on coffee, the urgent need for Pan-American solidarity during the war persuaded the United States to join with fourteen Latin-American coffee-producing countries in a scheme for wrestling with the problems created by the closing of European markets. The inter-American coffee agreement remained in force throughout the war years and terminated in 1948. The agreement covered three basic annual export quotas, i.e., (*a*) for exports from the fourteen producing countries to the United States, (*b*) for exports to the United States from other sources, (*c*) for exports by the fourteen countries to markets outside the United States. During this time the promotion of demand stepped up coffee consumption from 14 lb. to 19·3 lb. per head, despite a period of rationing for eight months between November 1942 and July 1943.

Now that we know that increased planting is taking place on a considerable scale, we should be forewarned and prepare for a break in prices and another period of overproduction in the future. Plans should be in readiness to assist the absorption of our own Commonwealth production within our own sphere of interests in Europe and the Middle East. One of the urgent needs is the

adoption of a lively promotion of demand, and this can be effected only by concerted action on the part of Commonwealth producers. In the past, growers have concentrated on production alone, leaving the coffee merchants to dispose of their coffee. This may not suffice in future. Commonwealth producers should themselves take an interest in the sale and encouragement of consumption of their coffee within the Commonwealth.

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